Essays on Voting, Cheap Talk and Information Transmission

By

Saptarshi Prosonno Ghosh

A Thesis Submitted to the University of Birmingham

for the Degree of Doctor of Philosophy

Department of Economics

Birmingham Business School

College of Social Sciences

University of Birmingham

September 2012

Abstract

The first part of the thesis studies the voting behaviour of careerist experts in a secret committee where voting profiles get 'leaked' to the public with a given probability. For informative voting (where every expert votes according to his posterior probability) in equilibrium, the committee must use the unanimity voting rule along with an intermediate probability of transparency. No committee that enforces informative voting can maximise social welfare, that is, informative voting and welfare-maximisation are mutually exclusive properties. Either full transparency or complete secrecy is required in a committee under the unanimity voting rule to maximise welfare. For low priors, a fully transparent majoritarian committee is better for the society than any unanimous committee. In the second part of the thesis, the transmission of information is studied where an informed media, whose interests are partially in conflict with a finite group of rational voters, transmits news items in an attempt to manipulate democratic decisions. In a common-interest two-alternative voting model where due to reputation concerns the media can credibly commit to send any news reliably, we show that even if voters welcome the news when it arrives, media's presence can hurt their ex-ante welfare in both large and small constituencies.

Acknowledgements

I would like to extend my special thanks to my principal supervisor Jaideep Roy for his invaluable advice and guidance during every step of this thesis. I would also like to thank my second supervisor Peter Postl for his constant encouragement and support. I express my gratitude to Ralph Bailey, Sandro Brusco, Jayasri Dutta, Marcin Dziubiński, Chirantan Ganguly, Parikshit Ghosh, Gilat Levy, Heracles Polemarchakis, Indrajit Ray and Anil Somani for very helpful comments and suggestions during several stages of the work. Parts of the thesis have been presented at the British Academy Workshop on 'Communication in Teams', 2010 at the University of Birmingham, the Indian Statistical Institute Delhi and Kolkata Centres, the Jawaharlal Nehru University, New Delhi and at the XIth Meeting of the Social Choice and Welfare, New Delhi. I thank the participants there for their remarks and questions.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

Decision-making under imperfect information is a challenge that is faced in the context of many economic activities. It is also natural that in a number of cases, there may be asymmetric information among the parties involved in the process. It is plausible that the participating agents may be driven by different (possibly conflicting) motivations. It is in this context that the issue of transmission of information gains importance. Often, the decision-maker who has to make a choice has inadequate knowledge of the costs and benefits of the choice he is about to make. Therefore, he may find it advisable to constitute a committee comprising of a single/multiple expert(s) who are supposed to provide recommendations regarding the state of the world based on their specialized knowledge. For example, a political leader may hire trained economists to advise him on the repercussions of a policy that is being debated. Again, a commercial firm may also solicit advice from a technical committee comprising of skilled experts when it is considering making an investment for research and development in a specialized field.

This thesis develops models that seek to explain the nature of information transmission when the senders of information are either solely motivated by career concerns, or are ideologically driven in favour of a particular alternative. Either of these scenarios is easily motivated. Reputational concerns are the driving force of the experts in a variety of professions. Another issue which the thesis covers is the heterogeneity in the quality of information of the experts who constitute the committee. This heterogeneity may be explained by the facts that experts with better education or more reliable sources may be in possession of more precise information that their less educated or relatively less connected counterparts. The more precise the information of the expert is, the more "talented" he will be deemed to be. In real life, it often becomes difficult to have precise information regarding the talent levels of each of the experts who constitute a committee, and they are treated as equals at the beginning. Due to this, each of their opinions is given equal importance at the time of making the decision. The reputational objectives of each of the committee members may be captured in their efforts to come across as a highly talented expert, without explicitly caring for the particular alternative they recommend.

On the other hand, particularly in a political economy setting, the agents may be preferentially motivated in favour of a particular policy. The thesis involves the scenario where the decision makers have access to multiple sources of information, a constituent element of which is the information received from the sender. This situation is motivated by alluding to the fact that in the real world, there are multiple sources of information available at the disposal of agents when they have to make a choice, and they typically synthesise all the available information at the time of taking the final call. The rational sender should in turn be aware of the multiplicity of these sources of information at the time of transmitting information. For example, if the Government Health department has to decide to issue a public notice in favour of a particular vaccine, it also needs to consider the information the potential patients are likely to receive from their private medical practitioners. In the thesis, the instance of a media outlet transmitting information through public news broadcasts is studied. The receivers of this information are the voters, who themselves receive informative signals privately and cast their votes after having aggregated all the available information.

In Chapter 3, information transmission from multiple senders to a single receiver is studied, where multiple experts with career concerns provide recommendations to an evaluator. In Chapter 4 information transmission from a single sender to multiple receivers is investigated, where a media outlet transmits news to multiple voters. Another point of contrast is the following: in Chapter 3, the senders of information are the decision makers (who are the committee members determining the decision of the committee). However in Chapter 4, the opposite scenario is studied where the receivers of information (the voters) determine the outcome.

In Chapter 3, three experts solely motivated by career concerns who possess expertise in independent dimensions are considered. The sole objective of each expert is to convince an evaluator (who may be interpreted to be the public) that their level of expertise is high. The experts seek to achieve this objective through the process of voting for a particular alternative. In this context, a setting where the experts vote in a secretive committee is studied, wherein there is a possibility that their secret votes might get leaked to the public. The focus is on informative voting, where every expert votes in accordance to his best judgement, and social welfare, which in turn is the ex-ante gain of the society from a correct decision in every dimension. It is an established result that such informative voting cannot be implemented in a fully transparent committee. In this work it is found that it is not achievable in a fully secret committee either. It is shown in Chapter 3 that informative voting is achieved only when the secret committee uses the unanimity voting rule along with an intermediate probability of transparency, provided that the common prior is not too informative. Non-conformism or anti-herding is interpreted to be the inclination on the part of the expert to recommend the alternative which is considered to be less likelier one according to conventional wisdom. This is motivated by the fact that the experts know they will make a better impression in the public eye if they are able to correctly predict the alternative thought to be less likely by the society. In a transparent committee, the evaluator gets to see directly the alternative a particular expert has recommended while deciding on the expected level of expertise this expert possesses. The recommendations of the other experts in the committee are immaterial in this decision. The innate tendency to anti-herd is the only one at work in a fully transparent committee, and no other forces that may depend on what other experts have recommended arise in this case. When the committee is fully secretive, then the evaluator only gets to know the final decision of the committee and not the individual recommendations made by the committee members. These have to be guessed by the evaluator. Hence at the time of making a recommendation, a particular committee member has to consider the actions of his colleagues, which will determine the decision of the committee and in turn affect the impression the evaluator holds regarding the recommendation made by this particular expert. Hence in the analysis of the behaviour of fully secretive committees, the particular decision aggregation rule the committee operates under is significant, and the cases of unanimity and majority aggegation rules are separately analysed.

The unanimity rule is considered first, according to which the unconventional alternative (which is the less likelier alternative according to the social prior) will be declared as the committee decision only if all the experts recommend it, and the conventional alternative (which is the likelier alternative according to the social prior) will be the committee decision for all other cases. Here if a particular expert is pivotal, and recommends in favour of the unconventional alternative, then the committee decision will be in favour of the unconventional alternative. In this case the evaluator will infer perfectly what the recommendation of the expert has been, even though the committee is secretive. This follows from the particular aggregation rule (unanimity) the committee operates under. However, if the expert recommends in favour of the conventional choice, then the committee decision will be in favour of the conventional choice, and in this case the evaluator will not be sure what the expert had individually voted for. For instance, it could have been possible that he had personally voted for the unconventional alternative, but any or all of his colleagues had voted for the conventional choice that leads to the decision of the committee to be in favour of the conventional choice. Alternatively, it could also be that his colleague had voted for the unconventional choice, while he himself had voted for the conventional choice that rationalizes the committee decision to be in favour of the conventional choice. Hence, if the pivotal expert votes in favour of the unconventional choice, he essentially makes his private recommendation fully known to the evaluator in spite of the full secrecy of the committee. However, if he votes for the conventional choice he is able to make his recommendation noisy in the eyes of the evaluator. Whether his private recommendation should be made fully inferable or kept noisy is therefore an endogenous decision that has to be made by the expert operating in a fully secret committee operating under the unanimity rule. The experts with mediocre talents are not confident of their capabilities, and hence seek to vote in a way such that it becomes difficult for the public to ascertain exactly what their private advices were. This objective is achieved by recommending in favour of the conventional choice. Therefore under unanimity, the mediocre expert is tempted to be a conformist and vote in favour of the conventional choice in order to disguise his personal vote from the public. However, as explained before, there is an incentive for the careerist expert to be a non-conformist and vote for the less likelier choice in a transparent committee. It is shown in Chapter 3 that there exists optimal degrees of transparency which perfectly counter-balances the two forces of excessive non-conformism or excessive conformism to induce a scenario where careerist experts with all possible levels of talent vote according to their best judgments.

A fully secretive committee operating under the majority rule is considered next in Chapter 3. Here unlike the case where the fully secretive committee works under the unanimity rule, the pivotal voter can never make his personal recommendation perfectly apparent to the evaluator. So unlike the unanimous committee case, there is no incentive for the pivotal mediocre voter to vote for the conventional choice in order to keep his personal recommendation vague. However, due to the inherent rationale of non-conformism in transparent committees explained earlier, the experts remain tempted to be overly non-conformistic even in a secretive committee under majority rule. Under no degree of transparency can they be made to vote according to their best judgments, for unlike the unanimity case there is no opposing force to counter-balance their innate non-conformism.

Welfare issues are addressed next, where the society gains when the aggregate committee decision is in accordance to the true state in a particular dimension, and loses when the two do not match. From welfare maximization it follows that it may not be optimal for the experts with mediocre talents to recommend in accordance to their best judgments. This result depends crucially on the following: the talent levels of the experts are heterogeneous, the weights assigned to the votes of all the experts are equal, and every dimension is equally important in the welfare function. Suppose two of the experts are highly talented while the level of talent of the third is mediocre. Suppose also that according to their best judgment in their respective dimensions, the two smart experts feel that the correct recommendation to be made should be in favour of the unconventional state. However, suppose the private information received by the mediocre expert be such that he feels that in his dimension of expertise, the correct recommendation to be made should be in favour of the conventional state. But if the voting rule requires unanimity for the action favouring the unconventional state to pass, it shall not be passed as the committee decision. This hampers aggregate welfare, because even though the mediocre expert has voted according to his best judgment, the quality of information at his disposal is low owing to his mediocre talents. In this case to maximize ex-ante welfare, the weak expert should exhibit an inclination towards non-conformism. Furthermore, it is also shown that unlike the quest to make every expert vote according to his best judgment, if we focus on ex-ante welfare maximization, then one requires either a fully transparent or a fully secretive committee under the class of unanimity aggregation rule. This leads to the following conclusion: Informative Voting (which means voting according to best possible judgment) and Aggregate Welfare Maximisation through committee decisions are mutually exclusive objectives if experts care about their individual reputations, know their own expertise and have private information in independent spheres of expertise. It is also shown in the same chapter that when the society is sufficiently divided over the two alternatives, a committee using the majority rule and operating with full transparency corresponds to higher level of ex-ante welfare for the society than any unanimous committee.

In Chapter 4, the scenario when a perfectly informed but biased sender (the media) transmits a public message to voters (who are partially informed themselves regarding the state of the world) is looked into. The setting is motivated by the fact that media outlets are often controlled by informed elites, whose preferences over alternatives are not perfectly aligned with that of the general public. The public constitute the electorate. This may lead to deliberate manipulation of social decisions by the biased media by suitably controlling the content of public news they choose to transmit. If however it is known that the media cares about his future reputation as a trustworthy source of information, then it can credibly commit not to send any incorrect information, even though it is possible for it to transmit vague information. If the media outlet is not concerned with future reputation, then it can potentially send both vague as well as incorrect information. In the model described in Chapter 4, the two following cases turn out to be identical: voter behaviour after receiving news from a media outlet that does not care about its future reputation, and voter behaviour when the media is absent. If the media is reputation-driven, then its credibility enhances its ability to manipulate the electorate. On the other hand, the power of a media outlet not driven by reputation to transmit information to the electorate is less, but so also is its power to manipulate. It then remains ambiguous what is better for the public: higher credibility (at a cost of higher ability to manipulate) or lower ability to manipulate (at a cost of low credibility). Given this ambiguity, in Chapter 4 we ask what are the theoretical consequences of the presence of reputational concerns in a media outlet on the welfare of the general mass. In this context, a common interest voting game is studied, where each of the voters have a common preference regarding the preferred alternative depending on the state of the world. There exists a media outlet whose preferences are only partially aligned to that of the voters, in the sense that for some states of the world the preferred alternative of the media and the voters are the same, while for others they differ. The media suffers prohibitive losses if it is found that it has delivered incorrect information by deviating from the message strategy in equilibrium. Hence the information provided by the media is “credible”.

Suppose the media chooses the message strategy that maximizes the ex-ante welfare of the media. Firstly, the case when a single voter (or decision maker, DM in short) is present is considered. It is shown in the model described in Chapter 4 that with a single DM, the presence of the media can never affect the welfare of the voter adversely. The intuition behind the result is the following: while deciding which alternative to vote form the DM uses two sources of information: his private signal and the public news transmitted by the media. Under certain scenarios, the informational content of the public news provided by the media can overwhelm the private signal of the DM and make him adopt a signal invariant action that makes him worse-off for some states of the world. However, the reliability of the news also enables him to choose his desired alternative with a higher probability for other states. Whether or not the DM finds the presence of the reputation-driven media ex-ante desirable or not depends on weighing these losses and gains. It is found that the potential gains outweigh the potential losses. In other scenarios, the provision of public news provided bolsters the action of the DM in the following manner: for some states of the world, it induces the DM to vote according to his private signal (which he would have done anyway even in the absence of the news), while for other states the informational content of the news leads the DM to choose his most preferred alternative without fail. Hence the DM always welcomes the presence of the media.

The case when the electorate is comprised of multiple voters who share a common preference over the available alternatives is considered next. However, each voter has access to private information about the state of the world. In the event that the prior of the voters is biased in favour of the alternative preferred by the media (this is termed as "small conflict"), it is shown that regardless of the size of the constituency, media presence can adversely affect the ex-ante probability of a correct decision and hence voters' welfare. Moreover, media presence will necessarily hurt voter welfare when the constituency is large. This may hold true even for small constituencies as well depending on parameter values. Considering the case where the prior of the voters is biased against the alternative preferred by the media (this is termed as "large conflict"), it is shown that for a sufficiently aware society, the presence of the media can both be beneficial and harmful for welfare. However, for a society where the level of awareness is low, the presence of the media is always welfare improving.

These results suggest that valuable news from a biased media is always welcome when the social decision is taken by a single DM, while as democracy spreads and the number of voters get large, a reliable source of news can in fact reduce ex-ante voter welfare.

The basic intuition behind this result is the following: Consider the multiple voter case where there is a small conflict between the voters and the media, and the precision of private signals of the voters is sufficiently high. As explained for the single DM case, here too the nature of new transmitted by the media is such that the voters follow a voting strategy that is invariant to the private signals they receive. This in turn implies that the probability with which the electorate arrives at the correct decision is independent of the number of voters, since their individual signals are not assimilated in their voting decisions, and information aggregation ceases. However, the voters invariably vote for their preferred choice for some states of the world, but are certainly misled into voting for their less preferred alternative for other states. On the other hand, had the media been absent, the voters would have voted according to the private signals they received, and hence the private signals would have been aggregated into the electoral decision. Hence in the latter case the probability of the making the right decision for all states would have been positively related to the number of voters. This is related to the Condorcet Jury Theorem, according to which if each of the agents of equal competence who constitute the electorate votes according to his private signal, then under majority, the probability of making the correct decision under majority goes to one as the size of the electorate goes to infinity. In the model described in Chapter 4, if the size of the electorate is large enough, then the advantage of aggregating the informative signals in the voting decision in the absence of the media is greater than the advantage gained from utilizing the content of the additional source of information in the form of news transmitted by the media (which in turn makes the private signals redundant). Hence the presence of the media sharing credible information with the public regarding the state of the world may reduce the ex-ante voter welfare compared to the case when no such credible information is available to the media.

Chapter 2

Related Literature

The basic question the thesis addresses pertains to information transmission. However, the settings in which the issue of information transmission is investigated brings the work to the purview of varied topics such as career concerns, cheap talk, transparency and secrecy of committees, public information, and voting. The experts who constitute the committee in the model described in Chapter 3 are solely driven by career concerns, without being concerned explicitly about the quality of their recommendations. In this context, papers which address career concerns of agents are discussed. The model in Chapter 3 also deals with transparency and secrecy of committees. This is a heavily debated topic, particularly in the wake of organisations such as the Wikileaks whose basic premise is that transparency in policy making ushers in a greater level of efficiency. The literature that draws comparisons between secretive and transparent committees is discussed. Furthermore, there is no explicit cost affixed to recommendations made by the experts in the model described in Chapter 3, or to the news transmitted by the media in the model studied in Chapter 4. Therefore, a connection may be drawn from these models to costless signaling models in the form of "cheap talk". In the model described in Chapter 4, the basic issue addressed is the effect of public information (in the form of information transmitted by the media) on voter welfare. In the same model, the receivers of information (the voters) themselves have informative signals regarding the state of the world. Drawing from these connections, papers that address the issue of efficacy of dissemination of public information, and those which describe information transmission where the receiver is imperfectly informed are discussed. In the model described in Chapter 4, the media does not diverge from the message strategy owing to reputation concerns. This may be motivated by considering verifiability in information transmission (as assumed in games of persuasion). In both the models described in Chapters 3 and 4, there is a voting mechanism at work, and papers that involve strategic voting are also briefly described.

We now look at some of the papers where agents are motivated by career concerns. Early works in this area include that of Fama (1980), Holmstrom (1999) and Scharfstein and Stein (1990). Fama (1980) looks at optimum compensation schemes for an employer and finds that if perfect monitoring is possible, the optimal compensation method is a periodic wage that pays on the basis of observed input. However, under regimes characterized by imperfect monitoring of inputs, compensation packages may give rise to a moral hazard problem where the employee provides inefficient amounts of input. Fama (1980) had argued that such moral hazard problems can be overcome if the employees have career concerns. Holmstrom (1999) investigates Fama's claim and studies how a person's concern for a future career may influence his or her incentives to provide inputs or make appropriate decisions. In the model, the person's productive abilities are initially unknown to every agent and are revealed over time through observations of performance.

An incentive problem arises from the person's motive to influence the learning process (which in turn influences the wage received), by taking unobserved actions that affect today's performance. The paper shows that career motives can be beneficial as well as detrimental, depending on the nature of alignment of interests between the principal and the agent. Scharfstein and Stein (1990) also consider careerist agents by assuming that there are two types of agents: "smart" agents receive informative signals about the value of an investment, while "dumb" agents receive purely noisy signals. Initially, neither the agents themselves nor the evaluator can identify the types, but the evaluator updates his beliefs about the quality of the agent based on: whether the agent made a successful investment, and whether the agent's behavior was similar to or different from other agents. The career concerns of the agents are captured in their urge to be favourably evaluated. The first component of the updating becomes less crucial if there exist systematically unpredictable components of investment value, for it then becomes feasible that smart managers could get unlucky and receive misleading signals, which in turn raises the significance of the second component. Agents are more favorably evaluated if they follow the decisions of others than if they behave in a contrarian fashion, which then gives rise to strategic herding. Hence agents ignore their private information and imitate the actions of others. Ottaviani and Sorensen (2006a) study careerist experts who privately receive a signal that is comprised of an informed and an uninformed source. The quality of experts may differ in the sense that it is more likely that the more talented experts will receive a private signal from the informative source. The talent levels of the expert is not known by any agent including the expert himself. The talent level of the expert is evaluated on the basis of the advice given and the realized state of the world. When sequential transmission of information with conditionally independent signals are considered, the paper shows that in the long run, learning is incomplete and herd behavior arises. In equilibrium, there is only a finite number of experts who speak informatively. If every expert speaks communicates informatively forever, then the amount of information revealed in each round necessarily converges to zero. Unlike Ottaviani and Sorensen (2006a), the paper by Visser and Swank (2007) assumes that talented experts receive the same signal, and identify a "conformity effect" among experts who have career concerns, and at the same time care for the quality of the decision they take. In this set-up, disagreement signals lack of competence as competent members view the consequences of the project in the same way. In this paper, similar to Scharfstein and Stein (1990), experts wish to convince the evaluator that they have voted in the same way. Hence the "conformity effect" may be identified in this context, wherein the reputational concern element in the payoff function of the experts makes them want to speak with one voice. In order to safeguard against the negative consequence of reputational concerns, it is warranted that the person with the least careerist motive should be made decisive, which in turn may be achieved by following the unanimity rule.

Strategic anti-herding or non-conformistic tendencies among careerist experts have also been identified in the literature. In Zwiebel (1995), careerist experts are evaluated on the basis of their relative performances. In the equilibrium, Zwiebel (1995) describes a scenario where average quality experts choose to herd and adopt less risky action so that they are evaluated against the standard benchmark, while high and low quality experts choose riskier actions. The high quality experts are encouraged to take the risk since they have access to better quality information, while the low quality expert is willing to make the riskier choice in an attempt to mimic the high quality type. Effinger and Polborn

(2001) analyze a model in which experts do not know their type, as in Scharfstein and Stein (1990). They study two experts motivated by career concerns providing advice sequentially, where the agent is most valuable if he is the only smart agent. This creates an incentive for an expert to maintain a degree of exclusivity in his recommendation, which prompts the second expert demonstrates anti-herding behaviour by proposing a different action than his predecessor, which may be in contradiction to his information set. In yet another paper demonstrating anti-herding behaviour among experts, Avery and Chevelier (1999) develop a model of decision-making when two agents have to take a binary decision sequentially. In their paper, the agents may either get informative signals about the state of the world, or may be completely uninformed. The paper addresses the case where the agents have different degrees of imperfect private information about their abilities. There exists a semi-separating equilibrium where the second agent, if sufficiently confident that her source if information is trustworthy, displays contrarion behaviour by not following the first agent's action and following her own signal, while the less certain second agent follows his own signal with some probability that depends on the particular signal received.

Levy (2004) was the first to show that reputational concerns alone are sufficient to generate anti-herding behaviour even for a single expert. In her model, anti-herding was interpreted to be the tendency of the agent to go against the conventional wisdom by prescribing the alternative the society feels is the less likelier outcome (as is reflected in the value of the social prior). Levy (2004) considers a decision maker who has a private signal about the state of the world, and the accuracy of this signal reflects the talent level of the decision-maker. There is a commonly known social prior, which determines which the likely state of the world is according to conventional wisdom. The decision-maker takes an action based on the prior and her own private information. An evaluator observes the state of the world, the prior, and the action taken by the decision maker and evaluates the accuracy of the signal received by the decision -maker, which in turn the decision-maker wants to maximize. It is found that in the unique equilibrium of the model, the careerist decision maker excessively contradicts the prior, in the sense that even when she believes that the prior is correct, she may recommend differently. The logic is that if the decision maker's action goes against the prior, it may be conveyed that the precision of her private signal own information is accurate enough to match the informative-ness of the prior. Hence going against public information may serve as a signal about ability, which implies that the decision maker might have an excessive incentive to use it. This makes the decision-make to distort her actions in this direction. Levy (2004) also considers the case where the decision-maker can choose to consult an informatively informed adviser who provides public advice. In equilibrium, the most able decision makers choose not to consult, since this choice itself signals that the level of precision of her private signal is high. The paper also examines whether advisers to the decision maker indeed report their information truthfully. If the adviser has career concerns himself, he manipulates his decision to come across as a highly talented type. Even if the adviser does not have any career concerns and is concerned only about the outcome, he biases his recommendations in anticipation of the anti-herding behavior of the decision maker. Thus, career concerns of either the adviser or the decision maker, are sufficient to induce sub-optimality in recommendation of actions.

We therefore see that career concerns in the part of the agents either induce conformism or anti-herding tendencies, which makes the agents not report truthfully. Ottaviani and Sorensen (2006 b) analyze this specific question in a reputational cheap talk setting and find that truthtelling is not implementable under very general conditions. They characterise information transmission by privately informed careerist experts, whose evaluation is conducted based on the recommendations they make and the state of the world that is realized expost. Ottaviani and Sorensen (2006 b) describe an equilibrium where the experts deviate from truth-telling (the nature and magnitude of deviation depend on the information structure considered). This is valid even when experts have private information about their own accuracy and care about their relative rather than absolute reputation. To understand why complete honesty is not achievable in equilibrium, suppose that the evaluator conjectures that the expert honestly recommends in accordance with the signal received. The quality of the expert is dependent on the precision of the private signal the expert receives regarding the state of the world. In a fully separating equilibrium, particular recommendations made is an indicator about ability, which in turn provides an incentive to the less able experts to mimic the recommendation of the highly able experts in order to create a better reputation for themselves. This in turn means that truth-telling cannot be sustained in equilibrium, where the expert's incentive to lie destroys any fully separating equilibrium where there is a perfect correspondence between the expert's signal and the recommendation made.

In the model described in Chapter 3, the issue of informative voting and welfare in secretive committees where there is a probability of mass leakage is addressed. There is a related body of literature that looks into the relative performance of fully secret or fully transparent committees. In some of these papers, committee members are solely motivated by their private preferences over the alternatives (Feddersen and Pesendorfer(1998), Austen-Smith and Feddersen (2006), Persico (2004)). However, more closely related are papers which focus directly on the comparison between secretive and transparent mechanisms wherein agents are motivated by career concerns. The papers according to which in the presence of career-oriented agents, a secretive committee performs better than a transparent committee are Gersbach and Hahn (2001), Stasavage (2007), Meade and Stasavage (2008), Fingleton and Raith (2005).

Gersbach and Hahn (2001) analyze a two-period model in which all or some committee members can be replaced after the first period. More specifically, they examine whether it is socially beneficial for the individual voting records of central bank members to be published when the general public is unsure about the efficiency of the constituent members, who in turn are aiming for re-election. In equilibrium, uninformed members mimic the informed ones when the process is transparent by randomising between the choices of the informed types. However, the uninformed types abstain when the process is secretive. The paper therefore identifies an intertemporal trade-off between transparency (which allows for better selection of committee members after the first period) and secrecy (which allows for better decisions in the first period). However, the expected overall losses are always larger in a transparent regime versus a secretive one. Gersbach and Hahn (2001) therefore argues that secretive processes perform better since it reduces the incentive of agents to distort their actions to signal their types. Stasavage (2007) investigates the idea that public debate helps to reduce polarization and promote consensus when compared to a private one, and finds the opposite to be true. In his model, the representatives have both decision and reputation concerns, the latter being in the form of showing loyalty to the constituents. If the reputation concerns are sufficiently strong, then at the time of public decision-making, the representatives face incentives to use their actions as a signal of loyalty to their constituents, even at the cost of ignoring private information about the true desirability of different policies. The constituents anticipate this sort of behaviour and hence do not alter their prior policy beliefs following a debate. When representatives instead make policy decisions in secrecy, they are more likely to allow private information to influence their actions. Meade and Stasavage (2008) develop a theoretical model of sequential information transmission within the framework of a three-member committee in which a known expert speaks first. All committee members are concerned both about the decision as well as their public reputation. The paper assumes that committee members are uncertain about the accuracy of their private signal. This setup is similar to Ottaviani and Sorensen (2001), who show that when a committee member who is known to have high expertise speaks first, subsequent careerist speakers may be induced to mimic the behaviour of the known expert rather than to reveal their private information accurately. This in turn is related to the contrarian behaviour displayed by agents as in Scharfstein and Stein (1990). In their paper, Meade and Stasavage (2008) have extended the set-up in Ottaviani and Sorensen (2001) to compare between transparent and secret deliberation. They show that the likelihood of having an informative equilibrium in which members accurately reveal private information is greater in the case of secret deliberation than public deliberation. When information is transmitted secretively, incentives of individual members are better aligned with those of the committee, since inferences about the quality of individual members will in this case be based on the quality of the committee's decision, rather than on the accuracy of individual recommendations. Hence the experts have more incentive to reveal their information in secretive committees. Fingleton and Raith (2005) studies strategic bargaining in which a seller and a buyer are each represented by an agent with reputation concerns. The difference in the quality of agents stems from their ability to obtain information about the other party's reservation price; neither principal knows the other's reservation price or her agent's type. The objective of each careerist agent is to be perceived as a skilled bargainer by his respective principal. Under transparent bargaining, the respective principals can observe the entire bargaining game as well as its outcome, while under secret bargaining they observe only the outcome. It is shown that agents unambiguously bargain more aggressively under transparent bargaining compared to secretive bargaining, and hence a less efficient bargaining outcome is reached under the former regime.

The papers discussed above therefore show that secrecy may bring about more efficient decisions because it presents less motives the incentives for agents to manipulate their actions in order to signal their types. Swank and Visser (2010) finds that imposition of transparency does not increase accountability as the experts would typically arrange pre-meetings and may reach informal understandings allowing them to come to the official 'transparent' meeting with one voice. Seidmann (2010) considers the case where the experts care for the decision as well as rewards received from outsiders to represent their interests. He shows that a secret committee reaches better decisions, because if the external rewards are high enough then the experts in a public committee tend to cast their fully visible votes in accordance to the interests of the outsider, even though it may not be informationally efficient.

In a different set-up, Gersbach and Hahn (2012) claim that a transparent committee performs better than a secretive committee by analyzing an inter-temporal model of committee decision-making where members differ in their levels of efficiency, which is their private information. The experts endogenously choose to acquire costly information that improves their chances of making a correct decision. The heterogeneity in the quality of experts arises from the requisite effort they need to put in to obtain correct information. In the second stage, the principal decides whether to retain the experts in the committee. The careerist committee members want to maximize the probability of their retention in the committee. This in turn induces them to acquire costly information and make the right choice, for that increases the probability of their re-appointment. Under transparency, the principal can evaluate the quality of a member by directly observing the individual's decisions, while under secrecy, he observes the collective decision alone. The paper shows that under transparency the principal is always better off in the first period, because it induces higher effort on behalf of committee members to acquire information and thus improves decision-making.

Levy (2007a) shows that there are strong motives for manipulation of actions for both the cases when the committee is fully transparent or fully secretive, and the intensity of distortion are contingent on the voting rule of the committee. The paper considers the voting behavior of career oriented experts (the paper considers a three expert set-up) with privately known skill levels in independent dimensions. Each of the experts have an informative signal about the true state in the dimension of his expertise, which eventually gets revealed to the public who in turn act as the evaluators of the skill level of the experts. The experts do not have any preference over the decision, and are solely motivated by career concerns so that their objective is to vote in such a way that portrays their perceived talent levels in the public eye to be as high as possible. In this scenario, Levy (2007a) compares the tendencies of the experts to exhibit conformist or non-conformist tendencies across different aggregation rules. The paper shows that conformist tendencies rise as the aggregation rule warrants more evidence for the unconventional alternative to be implemented. In a similar set-up but with two experts, Levy (2007b) shows that if the voting rule is biased against the decision advocated by the prior, then a transparent procedure corresponds to a higher level of welfare than a secretive one. If the voting rule is biased in favor of the decision advocated by the prior, however, a transparent procedure corresponds to a higher level of welfare when the prior is sufficiently weak, and a secretive procedure dominates when the prior is sufficiently strong. This result is re-inforced for a three-member committee in the model studied in Chapter 3, where it is additionally found that for a sufficiently weak prior, a committee operating under the majoritarian rule corresponds to a higher level of welfare than a committee which works under the unanimity rule, the latter being subject to any degree of leakage.

In their seminal work, Crawford and Sobel (1982) analyse information transmission between a perfectly informed but biased expert who sends a costless message to an uninformed receiver. There has been a large body of work that explore information transmission from a fully or partially informed agent to a partially informed or completely uninformed agent in varied settings, where the fundamentals of the model follow the basic set-up in Crawford and Sobel (1982). The model in Chapter 3 differs from the basic Crawford-Sobel framework in the sense that the senders of information are solely driven by career incentives and do not have a preference for any particular outcome. The model in Chapter 4 differs from the standard Crawford-Sobel framework in that there is partial alignment of interests between the sender and the receiver, in the sense that they match completely for some states of the world, but are different for other states. Crawford and Sobel (1982) show that in equilibrium, the information transmitted is partitional, and the degree of precision of information conveyed is determined by the magnitude of conflict of interest between the sender and the receiever. In their model, both state space and the action space is continuous, and for every state there is conflict of interest between the sender and the receiver. Crawford and Sobel (1982) show that the ex-ante payoff of the sender and the receiver is always increasing in the level of precision of information (reflected in the number of partitions) in equilibrium. The basic model proposed in Crawford and Sobel (1982) has been extended in several directions. Gilligan and Krehbiel (1989), Austen-Smith (1993), Krishna and Morgan (2001a), (2001b) consider multiple senders of information, while Farrell and Gibbons (1989) consider multiple receivers. Chakraborty and Harbaugh (2003), Levy and Razin (2007) consider multidimensional state spaces, while Battaglini (2002) considers multiple senders combined with a multi-dimensional state space. Aumann and Hart (2003), Krishna and Morgan (2004) consider multiple rounds of cheap talk. Unlike the unilateral transmission of information from the sender to the receiver as in Crawford and Sobel (1982), games where information is exchanged through costless signals with multiple players each of whom have payoff relevant private information is studied in Matthews and Postlewaite (1989), Austen-Smith (1990), Banks and Calvert (1992), Baliga and Morris (2002), Baliga and Sjostrom (2004).[1] Morgan and Stocken (2003) consider the problem of communication when the bias of the sender is private and unobservable. Depending on parameter values, they obtain either

[1] Farrell (1996), Farrell and Rabin (1996), Ganguly and Ray (2010) have conducted exhaustive literature surveys on cheap talk.

non-responsive or semi-responsive equilibria. In either case, the divergence of interests between the sender and the receiver makes communication noisy and reduces the amount of information that can be communicated in equilibrium. In the semi-responsive equilibrium, unbiased senders can credibly communicate bad news, but cannot credibly convey good news.

If a static cheap talk game is repeated, this may give rise to reputational concerns on the part of the sender, imposing additional constraints on costless information transmission between the sender and the receiver. The following papers address this question: Sobel (1985), Benabou and Laroque (1992), Morris (2001), Ottaviani and Sorensen (2006a). Analysing cheap talk in this repeated framework would require us to make assumptions about the nature of these reputational concerns. Typically, reputational/career concerns are motivated through two channels: the sender may care about appearing to be well informed (as is considered in the model described in Chapter 3, or it may also be optimal for the sender to have a bigger incentive to tailor the present information transmitted such that a false perception regarding his reliability is created that affects his future credibility and hence future payoffs. In the second context, Sobel (1985) provides justification why in a finite period setting it is profitable for a sender to build reputation by providing information even though there is conflict of interest, where after each stage the receiver assesses his credibility in order to judge how much to trust the information of the sender. Sobel (1985) considers a binary variable, the value of which the sender knows and sends a message to the receiver from a set of possible signals. Then the receiver takes an action, payoffs are received, after which the receiver observes the actual value of the variable and the game is repeated in the next period. The game in each period is of varied level of importance, which is exogenous and common knowledge. The receiver is uncertain about the sender's preferences, and believes with a given probability that the sender's utility function is such that the either the sender is a friend of the receiver, or an enemy. Once a cheating is exposed, the receiver believes that the sender is an enemy and information transmission for the future periods stop since the trust is broken. In this setting Sobel (1985) constructs an equilibrium in which it is optimal for the "enemy" sender to report truthfully with probability one in the rounds of relatively lower importance. Even though the sender suffers relative losses in these rounds, he builds trust with the receiver for the future (more important rounds). Morris (2001) considers a static cheap talk game where an informed sender wishes to convey her valuable information to an uninformed receiver who shares identical preferences, thereby having a current incentive to truthfully reveal his information. But if the receiver thinks that the sender might be biased in favor of one decision and the sender does not wish to be thought to be biased owing to future reputation concerns, the sender has an incentive to lie. If the sender is sufficiently concerned about his reputation, no information is conveyed in equilibrium. In Sobel (1985) it was assumed that a sender who is a "friend" always tells the truth. Morris (2001) therefore endogenizes the behavior of the "good" sender, and models the scenario where the "good" sender may have an incentive to lie (despite a current incentive to tell the truth) in order to enhance his reputation. Benabou and Laroque (1992) extend Sobel (1985) to study a binary-state, binary-action repeated game where the sender does not know surely the state of the world, but receives a noisy signal about it. In this context, there arises an opportunity for the strategic class of senders to distort their announcements, since the receivers cannot verify if the message was sent truthfully (owing to the fact that it is common knowledge that the private information of the sender may be erroneous, and possible deviations may be ascribed to be an honest mistake). Benabou and Laroque (1992) show that in the presence of reputation concerns, this tendency of the strategic class of senders to deviate from truth-telling is lessened. The paper shows that in the presence of the honest sender, the strategic sender may truthfully report the state of the world for long periods of time in order to establish a reputation for honesty, which is then subsequently used to manipulate the receiver. In a one-shot version of their game however, unless the sender is honest with probability at least one half, there exists only the babbling equilibrium in which no information is transmitted.

Information transmission in the case when the agents display bounded rationality has also been studied in Crawford (2003) and Chen (2011). Crawford (2003) considers a class of zero-sum two person perturbed Matching Pennies game played between a sender and a receiver. Before actually playing the game, the sender sends a costless, non-binding and noiseless message about his intended move to the receiver, after which the game is played. If all players are rational, then the messages must be uninformative. However, Crawford assumes both the sender and the receiver may either be naive or sophisticated. While the sophisticated player is fully rational, the naive player optimizes his action based on non-equilibrium beliefs which are independent of the strategies adopted by other players. Crawford (2003) constructs an equilibrium where the sophisticated receiver can systematically fool a sophisticated receiver by declaring a particular move and playing the other, provided the sophisticated receiver believes that the sender is naive with high probability. Chen (2011) extends the Crawford and Sobel (1982) framework by considering a sender who may potentially be honest or dishonest, and receivers who may be naive or sophisticated. For a finite message space, an honest sender always abides by the message strategy, whereas a sophisticated sender may deviate from it if he finds it optimal to do so. On the other hand, a naive receiver always trusts the message provided, whereas a sophisticated receiver discounts the message appropriately considering the motivation that might have prompted the sophisticated sender to send such a message. Chen (2011) shows that equilibrium action of the sophisticated receiver is not necessarily increasing in the messages he receives, even if the strategic sender follows an increasing strategy. This happens if the receiver believes with high probability that the message is coming from a dishonest sender who has pooled with an honest sender who has observed a high value of the state, and as a result discounts the message heavily.

The set-up in Chapter 4 is in line with games of persuasion, which may typically be described as sender-receiver games where costless messages may be sent, and where the information transmitted can be proved (this is known as the verifiability of certifiability criterion). In such games, one or more interested sender/senders try to influence the receiver/receivers by strategically providing or concealing information relevant to the decision. The analysis of persuasion games may be used to investigate welfare effects of provision of information from an interested sender to a decision maker. The earlier works in persuasion games were by Milgrom (1981) and Grossman (1981). Milgrom (1981) considers a sender with private information who can convey information or withhold it from a receiver in order to induce an action from the receiver, which in turn is taken into account by the receiver to deduce the sender's private information in equilibrium. Grossman (1981) showed that the seller is not able to mislead the potential buyer about the quality of his product, even in a monopolistic market in the absence of reputation concerns, if the information transmitted is verifiable. The intuition of this result is that the buyer will believe that the seller will only report favorable information, since the latter has the option to choose not to reveal any information. Since the models consider rational receiver/receivers who base their inferences taking into account the seller's incentives to withhold unfavorable information, voluntary communication results in full revelation of the preferences of the sender. This argument behind the fully revealing equilibrium is known as the "unraveling argument". The unraveling equilibrium, however relies on the principle that the receiver surely knows that the sender is fully informed. Shin (1994) has shown that if the receiver is uncertain about the sender's information (second order uncertainty), then a perfectly revealing equilibrium does not exist and this feature is also captured in Okuno-Fujiwara et al (1990). The reason for the failure of the unraveling argument and the non-existence of a fully revealing equilibrium in this setting is that the receiver is unable to distinguish between a sender who possesses information and remains silent and one who does not possess the information in the first place. Koessler (2004) studies the sharing of knowledge by adding a preliminary stage of non-cooperative communication to incomplete information games. Regarding the communication, it is assumed that only truthful communication is allowed in the sense that the sender cannot disclose any information that he does not possess. However, the players cannot commit to any information transmission mechanism prior to actually receiving the information. By using knowledge consistency conditions in equilibrium, the paper proposes sufficient conditions for the existence of perfectly revealing equilibria in some classes of games. Glazer and Rubinstein (2004) study a model wherein a speaker wishes to persuade a listener to accept a certain request. The alignment of the preference of the listener with the request made depends on the values in two dimensions, which are known to the speaker. The listener can check the value of a single dimension. The paper studies mechanisms that specify a set of messages that the speaker can send and a rule that determines the listener's response, where the mechanisms maximize the probability that the listener accepts the request when it is justified and rejects the request when it is unjustified, given that the speaker maximizes the probability that his request is accepted.

The issue of when it would be beneficial for the receiver to delegate the decision - making authority to the informed sender has been investigated in a number of papers. Dessein (2002) shows that when the receiver encounters a biased but better-informed sender, unconstrained delegation of decision-making to the sender is better for the receiver than cheap talk communication whenever the conflict of interests are not too large. Since the conflict of interest is common knowledge, after hearing from the sender the receiver tries to correct for the biased message when he chooses to decide the action himself instead of resorting to delegation. The sophisticated sender, in turn, anticipates this discounting and accordingly tailors his message, leading to loss of information. Hence in certain cases, delegating the job to the sender is better for the receiver than trying to glean information from the sender and acting by himself. The paper shows that in the standard Crawford-Sobel framework, if the state space is uniformly distributed, then for all levels of bias wherein informative communication is feasible, delegation is better for the receiver than communication. The main intuition is the following: in the equilibrium in Crawford and Sobel (1982), lower levels of conflict correspond to finer partitions in absolute terms. However, the partitions become coarser relative to the bias, that is, information entails more noise relative to the bias. Hence, when highly informative communication is possible, it is better for the receiver to delegate authority to the sender and avoid communication. Ivanov (2010) extends the Crawford and Sobel (1982) framework by introducing a preliminary stage where the receiver chooses the information structure of the sender denoted by the conditional distribution of signal generation given the state of the world. The information of the sender may be coarsened such that instead of knowing the state for sure, the sender will know if the state belongs to finite partitions. For the uniform quadratic specification, the paper shows that if informative communication is possible, then controlling the sender's information at the pre-communication stage is ex-ante better for the receiver than delegating to the sender. Regulation of information is also better for the receiver than receiving information from a fully informed sender as long as informative communication is sustainable. By suitably regulating the information content of the sender, the receiver can limit the sender's ability to distort information that is provided to the receiver, and thereby be better-off when compared to direct delegation in the process. In a separate setting that involves a voting environment with partially informed voters, the model described in Chapter 4 finds that it is never optimal for the voters to abrogate their voting rights and delegate decision making authorities to the media with whom their interests are only partially aligned.

In Chapter 4, the voters who act as receivers of costless signal from the media themselves have access to imperfect yet informative signals regarding the state of the world. In the literature, strategic information transmission when the receiver is privately informed is studied in Barreda (2010), Lai (2010), and Seidmann (1990). Barreda (2010) extends the Crawford-Sobel framework by considering the case where the receiver has access to imperfect yet informative private information apart from the message provided by the biased yet informed sender. The paper shows that in this setting, information provided will be partitioned in nature. When quadratic loss preferences are considered, it is shown that as the precision of the private information of the receiver rises, the sender may provide more vague information. In a separate setting, the model described in Chapter 4 finds that as the precision of the private signal of the receiver/receivers increase, the message transmitted by the sender will be more usable in the sense that the information will help the receiver/receivers make better decisions for all states of the world. In Barreda (2010), the receiver's private information may not adequately compensate for the loss in communication due to more vague information provided, thereby leading to a decline in welfare for both the receiver and the sender. Two effects are identified which arise as a result of the additional information which the receiver obtains. Firstly, the "information effect" that empowers the receiver to make better decisions on average due to his private information. This effect encourages the sender to transmit more vague information, since he is assured that the receiver will not choose an action too far away from the true state owing to his private information. Hence this effect discourages communication. However, there is also a "risk effect", since unlike the traditional Crawford and Sobel (1982) framework, the sender is no longer sure exactly which action his message is going to induce from the receiver, (which is also dependent on the latter's private information that is unknown to the sender). Since the sender is risk averse, he chooses to send more precise information to reduce the variability of the expected induced action of the receiver. Hence the risk effect encourages communication. It is shown that the information effect dominates the risk effect reducing communication in equilibrium. Lai (2010) studies strategic information transmission between perfectly informed sender and partially informed receiver, where the information set of the receiver is bi-partitioned such that he knows for sure which partition the state belongs to. The boundary of the partition is private information, and it is common knowledge that this threshold value is uniformly distributed over the state space. In this scenario, if the sender provides some information, it may either supercede, complement or falsify the private information of the receiver. In the paper, it is shown that exaggerated information provided by the sender will have a lower impact in inducing suitable action from the receiver, since the latter has assistance from an additional source of information. As a result, the expert exaggerates more and provides even less information compared to Crawford and Sobel (1982), which results in extending the length of the partitions for the high states and deletion of partitions for the low states. There exists a positive measure of information structure for which it may be possible for the receiver to be strictly worse-off compared to the case where he was uninformed. Hence this paper shows that for a single receiver, given information from the sender, private information of the receiver may hurt the welfare of the receiver. Seidmann (1990) considers a discrete state space with a privately informed receiver, where the ideal action of the sender is independent of the state. Here any message provided by the sender induces a distribution of the receiver's actions across its types (that depends on the private information of the receiver). This implies that there may be more than one message that induces distributions over actions that are not ordered by stochastic dominance. The different types of senders who agree in their preference rankings of non-stochastic actions may disagree in their preferences over the non-stochastic distributions, thereby making effective communication feasible.

There is also a literature which studies the impact of public information in binary action co-ordination games where agents have both private and public signals about some underlying state. This is linked to the model described in Chapter 4, as in that chapter we investigate how the introduction of public news through the transmission of news by the media outlet affects voter welfare. Hirshleifer (1971) studies the scenario where individuals are unsure only about the size of their own commodity endowments and/or about the profitability of their personal productive investments. It is shown that additional private information of an individual leads to his gain at the expense of his colleagues. But public information leads to re-directing productive decisions, and rational agents find it optimal to combine in order to generate public information through formation of public agencies such as the government. Angeletos and Pavan (2004) consider an environment of macroeconomic complementarity and study how the precision of publicly provided and privately collected information affect equilibrium allocations and social welfare. In their model the individual's return to investment is increasing in the aggregate level of investment and agents have different expectations about the underlying economic variables. The paper shows that welfare unambiguously increases with an increase in precision of public information, and policies that either disseminate more precise information about economic fundamentals, or reduce the variability of interpretation of policies, necessarily boost welfare. On the other hand, an increase in the precision of private information may reduce welfare by increasing the heterogeneity of expectations and impeding market coordination. This result is in contrast with Morris and Shin (2002), who show that public information may hurt welfare and private information proves beneficial. In particular, Morris and Shin (2002) consider a setup wherein the payoff of every agent is a weighted sum of two parts: the first part is the distance of his chosen action and the true state of the world; the second part depends on the average distance between the agent's action and the action profile of the entire population. Owing to this second term, there is an incentive for the agents to coordinate their actions, due to this externality each agent tries to second guess the decision of the other agents. With perfect information, each agent chooses his action to be equal to the true state of the world, and this maximizes social welfare defined in turn as the normalized average of individual utilities. The nature of public and private information is similar, both consisting of a signal that is composed of the true state of the world to which a random error term is added. The variability of the error term determines the precision of the information. In this set-up, if an agent observes a public signal that is lower than his private signal, then his expectation of others' expectation of the true state is lower than his own expectation of the true state. If the incentive to co-ordinate is sufficiently high, the action by every agent is closer to the public signal than what is informationally efficient, leading to a loss in welfare. Thus, the attempt the agents make to align their actions is socially wasteful. Hellwig (2005) studies the welfare effects of disclosure of public information in a setting of monopolistic competition among firms which vary in the levels of information at their disposal. This variation in information content may lead to delays in price adjustments and increases the effects of monetary shocks. If public information is provided, it leads to lower price dispersion and unlike Morris and Shin (2002), always leads to welfare improvement. In a more general setting, Angeletos and Pavan (2007) study the equilibrium and welfare properties for games characterized by strategic complementarity or substitutability in the presence of heterogeneous information. They show that complementarity increases the sensitivity of equilibrium actions to public information, while substitutability increases the sensitivity of equilibrium actions to private information, which increases cross-sectional dispersion. Cao and Hirshleifer (2000) consider a model of informational herding by incorporating word-of mouth learning, where agents are at liberty to observe not only past actions undertaken by other agents but also the outcomes arising out of those actions. In this context, they define an information regime to be fragile if at a particular time period, an induction of a public piece of information whose precision is not greater than that of the private information possessed by the single agent himself changes the behaviour of the next agent with positive probability. The paper shows that cascades may be formed that aggregate information inefficiently and are fragile. Gersbach (2000) studies the community members' desire to have public information in a collective choice process governed by a social choice function. The value of public information is the difference between the expected utility, when agents know that everybody will become informed, and the expected utility under ignorance. The paper considers heterogeneity among voters (in terms of preferences over outcomes) and shows that under certain axiomatic assumptions (non-decisiveness and Pareto) of the social choice function, there are payoff structures for every social choice function whereby an arbitrary subset of agents is worse off from public information. It follows therefore that the use of a social choice function for deciding whether to gather information can lead to the adoption or rejection of information gathering. In this context, Gersbach (1995) shows that if the aggregation rule is majority, then the majority is better-off if public information is acquired in the set-up when no distributional uncertainty exists and only two options are present.

With regards to committees, Condorcet (1785) argued that the majority of equally competent individuals who vote according to their own signals in an election with binary alternatives are more likely to make the optimal decision than a single individual. Also, increasing the number of informed committee members raises the probability that a correct decision is arrived at. Furthermore, the theorem states that the probability of making the correct decision goes to one as the number of committee members tends to infinity. In the theorem, Condorcet assumed that individuals always reveal their signal about the true state of the world. However, there are a number of papers which investigate the aggregation of information in committees where this particular assumption of agents voting non-strategically is dropped. It is shown that in case the agents are resorting to strategic voting, it may be that voters may not always reveal their signal about the true state of the world, and for these cases the Condorcet Jury Theorem may not hold. This is because under strategic voting, each particular voter considers the private information of the rest of the voters, and decides his own vote accordingly. In the process, it may be that his personal information may not be able to influence his voting decision in a decisive way. By incorporating strategic voting, a strand of literature (for example, Austen-Smith and Banks (1996), Feddersen and Pesendorfer (1996, 1998)) has examined the validity of the Condorcet Jury Theorem and made comparisons across different aggregation rules. Austen-Smith and Banks (1996) consider the following three voting strategies: "sincere" voting, which takes place when each voter votes on the basis of the prior and the private signal, "informative" voting, where the votes cast reflect the private signal of the voter, and "rational" voting, where the voting profile constitutes a Nash-equilibrium of the Bayesian game and represents strategic voting. They show that if the signal strengths are homogenous, then if the prior and signal strength are such that sincere voting is informative and rational, then it is possible if and only if aggregation rule is majoritarian, which is also true in the model described in Chapter 4. However, in Chapter 4 it is found that there may arise situations where the prior and signal strengths are such that sincere voting is no longer informative and rational. For these cases sincere voting is rational but no longer informative.

Feddersen and Pesendorfer (1996) provide an explanation for why voters abstain strategically from voting even though it is costless to vote. The paper considers a two-alternative voting model with finite voters having heterogeneous preferences operating under plurality rule. There are three types of voters: two types of partisans, who, regardless of the state of the world, prefer either one of the alternatives, and independents, who prefer to select the option that matches the true state of the world. Some voters receive a completely uninformative signal, while others receive a perfectly informative one. The uninformed independent voters' follow a mixed strategy of abstention and voting. The reason to cast a vote is to compensate for the partisans, thereby maximizing the possibility that the informed voters turn out to be pivotal in determining the outcome of the election. In the context of jury trials, there is a conjecture that the unanimity rule of conviction in trials would reduce the probability of convicting an innocent while increasing the probability of acquitting a guilty defendant. Feddersen and Pesendorfer (1998) investigate this claim in an environment of strategic voting by jurors. They study a two alternative voting model where each voter is privately informed. Voters vary with respect to their leniency, which is given by their threshold probability of the defendant's guilt above which they are prepared to vote in favour of sentencing by voting guilty. Each juror behaves as if he is pivotal and therefore, under the unanimity rule, additional information is revealed about the state of the world, which may overwhelm the private signal of the voter and cause him to vote with the others. Thus the probability of convicting an innocent defendant is bounded away from zero, and this holds even when the size of the jury is high.

Chapter 3

Professional Advice from Randomly Transparent Committees

3.1 Motivation

> "In the world of diplomacy, known for its ambiguity and opacity, the WikiLeaks organization says its function is to "keep government open." But with the release of some 250,000 American diplomatic cables, the outcome may be more ambiguous, closing doors to United States diplomats, turning candour to reticence and leaving many people leery of baring their souls and secrets to American officials."
>
> *The New York Times News Service*, Dec 5, 2010.

This chapter[1] studies voting behaviour of careerist experts (who have expertise in three independent and equally important dimensions) in a secret committee where voting profiles get 'leaked' to the public with an exogenously given probability. We focus on *informative*

[1]The contents of this chapter is joint work with Jaideep Roy.

voting, where every expert votes in accordance to his privately formed posterior probability and *social welfare*, which is the ex-ante gain of the society from a correct decision in every dimension. We show that for informative voting to be obtained as an equilibrium outcome, it is important that the committee uses the unanimity voting rule along with an intermediate probability of transparency provided that the common prior is not too informative. We then show that no committee that enforces informative voting can maximise social welfare (from the decision recommended by the committee), that is, informative voting and welfare-maximisation are mutually exclusive properties. Moreover, within the class of unanimous committees, randomness of transparency is never socially desirable so that either a fully transparent or a fully secretive committee is required under the unanimity voting rule in order to maximise welfare. We also show that with a low prior (the case where expert committees are most valuable to the society), a committee using the majority rule and operating with full transparency is better for the society than any unanimous committee. Many important decisions are taken by professional experts who care only about their reputation. They often operate in secret committees so that one seldom gets to know the personal opinions of these experts who constitute the committee. A considerable amount of past research has focussed on how reputational concerns affect incentives of experts to advise truthfully in different types of committees classified by voting rules, and also on whether secrecy is desirable or should committee voting be made fully transparent.[2]

[2] In contrast to the literature on professional experts, there is a large literature that investigates voting in committees where agents have private preferences over the outcomes. One motivation comes through the jury literature, particularly the Condorcet Jury Theorem (CJT) and Austen-Smith and Banks (1996) was the first to question the apparently innocuous assumption that voters vote 'sincerely', in a model where agents have private preferences over the outcomes. The conflict between informativeness and

We examine the issue of quality of professional advice obtained from a *committee with random transparency*, an institutional environment where experts act in a supposedly secretive committee but face an exogenous probability with which all their personal opinions are collectively 'leaked to the public (or an evaluator or a decision maker)'. Our focus is on two aspects of such expert advice: *informativeness* of individual recommendations and *aggregate welfare* from the decisions reached by the committees they represent. We analyse how these two properties are affected by the *transparency probability* and the *committee voting rule*.[3]

We study a model where three professional experts in independent dimensions (and possibly varying in their levels of expertise) constitute a committee that takes a binary decision (between two alternatives, A and B) via plurality voting. All agents start with a common prior biased towards choice B which is also shared by the public acting as the evaluator of their talents. Experts receive signals whose information content reflects their talents and talents are private information.

Once all experts in the committee have cast their votes, the committee decision is made public. The public then observes the true state in each dimension and may also observe the collective set of individual votes (if leaked). It then forms a belief about the true talent of each expert. The experts are solely driven by careerist goals in the sense that *ceteris paribus*, they strive to enhance their reputations in the eyes of the public that act as the evaluator of their talent. We characterise such a committee by the voting

welfare was also raised in their work where it was noted that apart from considering the implementability of informative voting strategies, the welfare considerations need to be taken into account as well. Gerling et al. (2005) provides a survey on these and other related issues.

[3]We lend special attention to situations where the common prior is not too informative as it is only then that the society would benefit most from recommendations of better informed committees.

rule (unanimity and simple-majority)[4] and the exogenous probability of transparency. Welfare from an individual expert's advice is then the gains made by the society when the committee decision matches with the observed state in that expert's dimension, or in other words, the decision taken is correct in accordance with expert's dimension of expertise . Likewise, an individual advice is *informative* if the expert's advice follows his privately formed posterior.

We build on the the large body of previous work regarding the behaviour of professional advisers or decision makers driven by career concerns. The seminal work in this area is by Holmstrom (1999), who finds that professional managers are averse to investing in projects which are more likely to reveal whether they are talented or not, and prefer to go with safer projects which hedge them more against investment failure. The concept of herding has been explored in Scharfstein and Stein (1990), where the experts wish to convince the evaluator that they voted in the same way.

The relationship between career concerns and herding have been addressed in a number of other works. In Zwiebel (1995), mediocre quality experts herd in order to set up a robust benchmark for the evaluator to judge their talents. In Ottaviani and Sorensen (2006a), the professional experts report sequentially and over time, the informative content of past reports overwhelm that of the current expert and he reports in accordance with the reports of the previous rounds by ignoring his own information. In contrast, there have also been papers where career concerns prompt the experts to 'anti-herd'. Effinger and Polborn (2001) identify the anti-herding effect where an expert is valuable

[4] In this binary set-up with B as the 'status quo' choice, the unanimity rule is biased towards B in the sense that the committee decision is A if and only if all experts provide advice in favour of A, and otherwise the status quo is upheld. Clearly, the simple majority rule does not suffer from such a bias.

if he is the 'only' able expert, hence he is encouraged to act differently than the ones preceding him. In one of the first works in reputational cheap talk literature, Levy (2004) showed that for a single expert (therefore in the absence of relative competition), absolute career concerns were sufficient to generate anti-herding behaviour by the expert. She interprets anti-herding to be the tendency of the expert to vote against the state which is the likelier one according to the prior. The concept of herding is analogously defined. In the model described in this chapter the concepts of herding and anti-herding are defined in a similar way. Ottaviani and Sorensen (2006 b) model the equilibrium behaviour of professional experts when expert advice deviates from truth-telling in a typical sender-receiver scenario but with the sender caring about his own reputation that is generated from the advice he provides (rather than the usual conflict of preferences over outcomes as in the seminal work of Crawford and Sobel (1982) and the vast literature around it). In their model, the quality of the expert's information is evaluated on the basis of the advice given and the actual state of the world realized ex-post, a feature that is present in our model as well. They show that their result on departure from truth-telling is valid both for the cases where the experts are aware or unaware of their own talent levels.[5] Like the model in this chapter, they also characterise the set of equilibria as a function of the prior belief on the state.

The link between herding (or anti-herding) in the presence of career concerns and the theory of committees was first studied in Levy (2007a). In particular, she compares a fully transparent with a fully secretive committee to show that career minded experts,

[5]The literature on reputation remains divided on the assumption whether an expert knows his type or not. Holmstrom(1999) and Holmstrom and Ricart i Costa (1986) assume that agents do not know their type, whereas Kreps and Wilson (1982) and Milgrom and Roberts (1982) assume that agents do know their type.

while voting strategically, exhibit conformist (herding) or non-conformist (anti-herding) tendencies so that at the end their votes may not be informative or efficient. Her work also highlights the importance of the voting rule used in such committees. We borrow the basic model from Levy (2007a) to check if these biased tendencies are corrected with random transparency.[6] Levy (2007a) finds that if the common prior is sufficiently biased towards the status quo alternative, a secretive committee with the unanimity rule induces the highest level of welfare. We show that this is not a local result as it is robust to the possibility that transparency can be random (and smooth). However, Levy (2007a) does not report welfare results when the prior is not too biased. We show that for low values of the prior, the opposite result holds where secrecy hurts welfare and it is optimal to have perfectly transparent committees if one is confined to the unanimity rule.[7] Interestingly, we also find that in every such situation of low prior, the simple majority rule yields the maximum level of aggregate welfare.

3.2 The Model

There are two possible actions A and B. Information about which should be the 'correct choice' is available from three equally important and independent sources (or *dimensions*), called $1, 2$ and 3 (where each dimension can be thought of as an independent criterion to

[6]The model we study is a generalization of the model used in Levy (2007a) where only the two extreme cases of fully transparent and fully secretive environments are studied.

[7]The model in this chapter also sheds light on Levy's (2007b) welfare characterisation for the unanimous rule by considering a more general setting with random transparency. Moreover in Levy (2007b), the analysis was confined to two member committees, as the goal of that paper was to characterise welfare in terms of voting rule biases for or against the prior. Therefore in the paper the welfare implications for the simple majority rule could not be looked into.

judge the merits of each action).[8] The true *state* in dimension i is denoted by $w_i \in W = \{a, b\}$, $i = 1, 2, 3$, with the following interpretation: B is the *correct action according to dimension* i if and only if $w_i = b$. Let $\mathcal{W} = \{a, b\}^3$ with $w = (w_1, w_2, w_3) \in \mathcal{W}$. Let $\pi_i = \mathbf{Pr}[w_i = b] > 1/2$ be the *common prior* for dimension i. For tractability, we assume that $\pi_i = \pi$ for each $i = 1, 2, 3$.[9]

The choice of an action is determined by a *committee* composed of three *experts* called $i = 1, 2, 3$. Expert i is a specialist exclusively in dimension i and receives a private signal $s_i \in S = \{a, b\}$ about the true state w_i in his dimension of expertise. The informative precision, denoted by t_i, of the signal s_i is called expert i's *talent*, with $t_i \in T = [1/2, 1]$, i.e.,

$$\Pr[s_i = a | w_i = a] = \Pr[s_i = b | w_i = b] = t_i.$$

Individual talents are private information and remain so throughout; however, it is common knowledge that they are *uniformly and independently* distributed over the support T.[10]

Expert i gives an *advice* $m_i \in M = \{a, b\}$ simultaneously and independently along

[8]The degree of inter-dimensional dependence is unimportant if the committee is fully transparent. As our focus is isolating the effect of career concerns in a secretive set up, we have maintained this flavour of transparency by keeping the dimensions completely uncorrelated. In section 4 we informally address the issue of correlated dimensions.

[9]Since $\pi > 1/2$ one may think of B as the conventional choice or the choice the 'society' or the 'decision maker' would have taken in the absence of the committee, assuming, as we do implicitly, that the public's preferences over outcomes is anonymous.

[10]A model with the above characteristics can be extremely meaningful in medical practice, large body public construction schemes, warfare, EU committees where each expert represents a single member-state of the union or any other area where there are many equally and uncompromisingly important dimensions of uncertainties for which one needs to respect the opinions of several specialized experts of different talents.

with the other experts and the advice (or simply *vote*) a (likewise b) is construed as the statement that "a (likewise b) is the true state according to dimension i". Denote by $\mathcal{M} = \{a, b\}^3$ as the space of vote profiles with $m = (m_1, m_2, m_3) \in \mathcal{M}$. The *decision* of the committee is denoted by d_x and is defined by the *voting rule* $x \in X = \{2, 3\}$ as follows: $d_x : \mathcal{M} \to \{A, B\}$ aggregates dimension-dependent advices to recommend an action such that $d_x = A$ if and only if $|\{i : m_i = a\}| \geq x$. If $x = 2$ we call this *majority* while if $x = 3$ we call this *A-unanimity* (or, unanimity in short).

The true states w_i, $i = 1, 2, 3$, become known to the public only after votes are cast and the committee decision d_x (that is always observed by the public) is reached. A *randomly transparent committee* is then a pair $\mathcal{C} = (x, p)$ consisting of a secret committee of three experts with voting rule x and the probability $p \in P = [0, 1]$ with which the voting profile $m = (m_1, m_2, m_3) \in \mathcal{M}$ is revealed to the public.

We shall use the term *terminal node* to denote the tuple (m, w). It is reached 'only if' the public observes the voting profile and the states. Call $\mathcal{I} = \mathcal{M} \times \mathcal{W}$ the set of all terminal nodes. Let ζ_i be a conjecture held by the public about how expert i plays and let τ (defined rigorously later) be the *talent evaluation function*, which is the Bayesian posterior expectation held by the public about the talent t_i of expert i at each terminal node $(m, w) \in \mathcal{I}$. The *pay-off* function of expert i is simply τ.[11] The experts are risk neutral and vote in order to maximise *expected payoff*, conditional on their talent and their private signal. The above environment gives rise to a 3 - player strategic voting game where the time line is as depicted in figure 1.

In the following section, we make precise the notions of strategies, evaluation functions,

[11]We drop the subscript i and so avoid writing τ_i as the τ function is simply a Bayesian update and hence the experts' identities in that function are irrelevant.

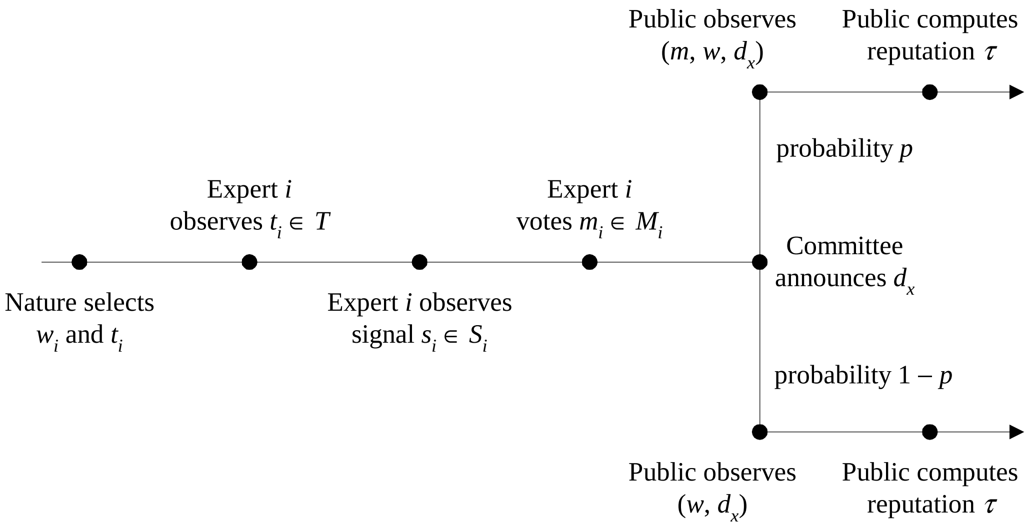

Figure 3.1: Time line of a randomly transparent committee (for $i = 1, 2, 3$ and for a given prior π on the states in each dimension).

informative voting and aggregate welfare.

3.3 Evaluation of Talent, Informative Voting and Aggregate Welfare

As in any standard model of strategic voting, experts provide advice as if they are *pivotal*. Denote expert i's *voting strategy* by σ_i, which is a function $\sigma_i : T \times S \times P \times X \to M$. It is a complete specification of how expert i would vote when she is of type $t_i \in T$, receives a private signal $s_i \in S$, faces transparency with probability $p \in P$ and the committee follows the voting rule $x \in X$. Let Σ be the space of all such voting strategies for expert i.

The *conjecture* ζ_i held by the public about the experts' voting strategy σ_i, is a function $\zeta : T \times S \times P \times X \to M$. The conjecture states explicitly, via the voting strategy σ, the vote $m_i \in M$ that expert i would cast if her type is $t_i \in T$, receives a private signal

$s_i \in S$, faces transparency with probability $p \in P$ and the committee follows the voting rule $x \in X$. We let $\mathcal{Z}$ be the set of all such conjectures on expert i, $\zeta_i \in \mathcal{Z}$. This conjecture leads to the beliefs we need to specify in order to define a Bayes Nash equilibrium via the public's expectations about t_i.

The talent evaluation function is then $\tau : \mathcal{I} \times \mathcal{Z} \to [1/2, 1]$, $i = 1, 2, 3$, with $\tau(m_i, w_i, \zeta_i) = \mathbf{E}(t_i | (m_i, w_i), \zeta_i)$ being the expectation held by the public about the true value of expert i's talent at node (m, w), given the conjecture ζ_i. The derived expressions for τ are provided in the Appendix 2 in subsection 3.7.2.

The public learns the true state w_i for each dimension i, updates beliefs on t_i, in the process generating a Bayesian probability belief α_{d_x} that $m_i = a$.[12] It is important to note that experts keep in mind α_{d_x} when advising. However, α_{d_x} depends, among other things, on w_i, $i = 1, 2, 3$ which expert i does not observe at the time he advises. As far as w_i is concerned, he forms beliefs about it's true value using π, s_i and t_i, while for w_j and w_k, he only uses π. Consequently, an expert forms an expectation about α_{d_x} given the fact that he votes as if he is pivotal. We denote this expectation by α.[13] The formal expressions for α_{d_x} and α will be derived and used directly in the proof of Proposition 1. Given α and the transparency probability p, an expert forms an expectation about the public evaluation about himself based upon his private signal s_i. In what follows, this *final* expectation held by an expert shall be denoted by the operator $\mathbf{E}_{s_i}$.

We are now ready to define a Nash equilibrium of the game.

[12] To be sure, it leads to degeneracy in the event m becomes publicly known. Also note that if m_i and w_i are observed (for example, when leaked), then the evaluation of t_i becomes independent of (m_j, m_k) and (w_j, w_k).

[13] Note that α is meaningful only if the voting profile m is not revealed as otherwise α_{d_x} becomes degenerate.

Definition 1. *A strategy profile* $\sigma^* = (\sigma_1^*, \sigma_2^*, \sigma_3^*)$ *constitutes a* Nash equilibrium *of the above Bayesian game if, given* $\zeta^* = (\zeta_1^*, \zeta_2^*, \zeta_3^*)$*, each expert* i *adopts a strategy which is optimal for him, i.e.* $\mathbf{E}_{s_i}[\tau|\sigma^*] \geq \mathbf{E}_{s_i}[\tau|(\sigma_i, \sigma_{-i}^*)]$ *for any* $\sigma_i \neq \sigma_i^*$.[14]

Let $\mu_{w_i} = \Pr[m_i = a|w_i, t_i, \zeta^*]$. Given a randomly transparent committee $C = (x, p)$, we say that expert i's voting is *state-reflective* if $\mu_a > \mu_b$.

The standard representation of voting strategies in this environment involves the notion of a cut-off talent that identifies an expert who is indifferent between voting a and b when she receives a signal $s_i = a$ against the common prior.

Definition 2. *A voting strategy* σ *is called a* cut-off strategy *if there exists a* cut-off talent $t(x, p; \pi) \in T$ *such that* σ_i *prescribes the following:*

$$m_i = \begin{cases} b & \text{for all } t_i \in T \text{ if } s_i = b, \text{ and for all } t_i \leq t(x,p;\pi) \text{ if } s_i = a, \\ a & \text{otherwise.} \end{cases}$$

The above strategy is state-reflective. We now define the notion of *informative voting*. Let $v(\pi, t_i|s_i)$ be the *posterior* probability-belief held by an expert with talent t_i who receives a private signal s_i that the true state of his criterion is $w_i = a$.

Definition 3. We say that expert i's voting strategy σ_i is *informative* if σ_i implies the following: $m_i = b$ if and only if $v(\pi, t_i|s_i) \leq \frac{1}{2}$, and $m_i = a$ otherwise. A randomly transparent committee $C = (x, p)$ shall then be called *informative* if there exists a Nash equilibrium σ^* of the 3-player strategic advice game induced by $C = (x, p)$ such that σ_i^* is informative for all $i = 1, 2, 3$.

Informative voting implies the following: despite being driven by the reputation they would earn, each expert would advise the action A if and only if her privately formed pos-

[14] As in Ottaviani and Sorensen (2006) and Levy (2007a), this is a weak equilibrium notion as no restrictions are imposed on the public's conjecture when observing behaviour off the equilibrium path.

terior probability is such that she actually believes A to be the correct action with higher probability than B according to her dimension of expertise. Note that this is a different (and perhaps more useful) criterion to consider than the case where the message sent by the expert is a direct revelation of the private signal he receives. This is because the talent levels of the experts (known to the expert concerned) are heterogeneous and never observed by the public. Therefore, informativeness implies the following: each expert uses his private signal, talent level and the prior to calculate the posterior probability and votes according to that.

While informativeness of committees is an important feature and well addressed in the literature on related papers, in a model where experts can be ex-post heterogeneous in their talents, there may arise a conflict between informative voting and committee decisions that are desirable by the society, for example if a decision supported by highly talented experts is stalled by a relatively unskilled vote against it. If the public is aware that the committee decision will be implemented, they would at the end care about the probability of the decision being correct. We ask whether this conflict between informative voting and probability of correct committee decision can be mitigated via appropriate choices of the voting rule x and transparency probability p, or is it always in the interest of the public that some experts lie. To address this in the present framework, Levy (2007a) uses an aggregate welfare function and below we propose a generalisation of that.

Let $\alpha, \beta \in \mathbf{R}$, with $\alpha > \beta$. Suppose the society gains α *utils* whenever the decision is correct in a particular dimension and β if it is wrong. The aggregate welfare under a randomly transparent committee $C = (x, p)$ at prior π is given by

$$W(x,p,\pi) = \sum_{w \in \mathcal{W}} Pr(w)[(Pr(d = A|w, x, t(x,p;\pi))\times$$
$$\sum_{k \in i,j,h} I_k^a + (Pr(d = B|w, x, t(x,p;\pi)) \sum_{k \in i,j,h} I_k^b]$$

where, for $z \in \{a, b\}$ in dimension k, $k = 1, 2, 3$, we have

$$I_k^z = \begin{cases} \alpha & \text{if } w_k = z \text{ and} \\ \beta & \text{otherwise.} \end{cases}$$

Remark 1. If $\alpha = 1$ and $\beta = 0$ (as used in Levy 2007a), then welfare becomes equivalent to the aggregate probability that the committee's decision d_x is correct (ex-post) on as many dimensions as possible (sometimes referred to as the *information aggregation criterion*). As our results on welfare are ordinal, we shall show that truthful voting can *never* lead to efficient information aggregation.

In the next section we address our two main concerns: whether there exists an informative committee and which committees maximise aggregate welfare.

3.4 Quality of Advice from Expert Committees

We begin by characterising randomly transparent committees which are informative. We show that majoritarian committees are never so while unanimous ones are provided the probability of leakage of individual votes takes an intermediate value and the prior is not too biased towards alternative B. We make this precise in the following proposition.

Proposition 1. *Consider a randomly transparent committee $C = (x, p)$ with voting rule $x \in \{2, 3\}$ and transparency probability $p \in [0, 1]$ and let $\pi \in (1/2, 1)$ be an arbitrary common prior. Then in equilibrium, the following is true:*

1. *If $x = 2$ then for all $p \in [0,1]$ and for all $\pi \in (1/2,1)$, $C = (x,p)$ is not informative;*

2. *If $x = 3$, then there exists $\tilde{\pi} \in (1/2,1)$ such that (a) for each $\pi < \tilde{\pi}$, there exists $p \in (0,1)$ such that $C(x,p)$ is informative and (b) for all $\pi \geq \tilde{\pi}$ and all $p \in [0,1]$, $C = (x,p)$ is not informative.*

The proof of the above proposition is moved to Appendix 1. In order to uncover the logic of the above result, we first note that only an expert i with a low talent will ever be indifferent between $m_i = a$ and $m_i = b$, while experts with high talents will likely be inclined to follow their personal signals. Given this, we can identify the following forces that affect the way the experts vote.

Non-conformism or anti-herding is promoted by virtue of an innate tendency to provide advice in favour of the unconventional choice (A, in our model), given the fact that the experts know they will be hailed by the public as more talented if they can correctly predict an outcome the public initially thinks to be less possible (since $\pi > 1/2$). This tendency gets stronger higher the value of the prior is and always works in favour of recommending the state as a. This is the only force at work when the committee is fully transparent ($p = 1$). Hence reducing the probability of transparency helps dampen this tendency to anti-herd.

In the case when secrecy of committees is guaranteed ($p = 0$), we need to look separately at the unanimous and the majority committees to analyse the different forces at work. Consider first the unanimity rule ($x = 3$). Here if the expert is pivotal and advises $m_i = a$, thereby throwing his weight on the action A, the committee decision will be A, and the public will clearly know that her personal message was indeed a. Notice that in this case, the non-conformist force will be at play again as it then becomes essentially a transparent committee with $p = 1$. However, if he recommends $m_i = b$, then while the decision will be B, the public will not be sure what she individually voted for. Hence, whether his private recommendation a 'should be fully revealed' or he would recommend b making his recommendation noisy in the eyes of the public is a decision the pivotal expert takes strategically. The experts with mediocre talents are not confident of their capabilities, and hence seek to vote in a way such that it becomes difficult for the public to ascertain exactly what their private advices were. This objective is achieved by voting b. So under unanimity, the mediocre expert is tempted to be a conformist and vote in favour of the choice B in order to disguise his personal vote from the public. With these opposing forces at work, the rest of the proposition relies on purely quantitative aspects and we show that there are degrees of transparency under which the two forces will counter-balance each other and elicit informative voting from all types of experts.

Now consider $x = 2$ under full secrecy ($p = 0$). Note that unlike in the case with $x = 3$, here, irrespective of whether the pivotal expert votes for a or b, he can never make it perfectly clear to the public what he himself voted for. Given this, while a 'wrong advice' is not so harmful for the expert's reputation, he is not rewarded enough for a correct advice either. However, due to the inherent rationale of non-conformism explained earlier, the experts remain tempted to be overly non-conformist, even in a secretive ($p = 0$) majoritarian committee and hence informative votes cannot be elicited from them.

Having understood if and when informative voting can be sustained, we move on to welfare issues. The next result compares the welfare properties of committees working under different aggregation rules and under different transparency probabilities.

We have the following proposition which holds independent of the welfare intensities α and β and hence we prove a very general result on welfare.

Proposition 2. *Consider a randomly transparent committee $C = (x, p)$ where the voting rule is x and where p is the transparency probability. Then, for all $\alpha, \beta \in \mathbf{R}, \alpha > \beta$, the following is true in equilibrium:*

1. *$C = (x, p)$ is informative if and only if it is not welfare maximising.*

2. *Suppose $x = 3$. Then there exist two threshold levels of the common prior, $1/2 < \pi^* \leq \pi^{**} < 1$ such that (a) for all $\pi < \pi^*$, aggregate welfare is maximised if and only if $p = 1$, and (b) for all $\pi > \pi^{**}$, aggregate welfare is maximised if and only if $p = 0$.*

3. *There exists a threshold level of the common prior $\hat{\pi} > 1/2$ such that for all $\pi < \hat{\pi}$, a fully transparent (i.e. $p = 1$) majoritarian (i.e. $x = 2$) committee is socially better than a unanimous ($x = 3$) committee with any transparency probability $p \in [0, 1]$.*

The proof of the above proposition is moved to Appendix 1 in subsection 3.7.1. The results provided in Proposition 2 stem from the facts that the talent levels of the experts are heterogeneous and the weights assigned to all the dimensions, as well as the votes of all the experts are equal. Suppose two of the experts are highly talented while the third is weak. Suppose also that according to their best knowledge (posteriors $v(\cdot)$), the two smart experts feel that A should be the correct choice (the probability of this happening is inversely related to the prior π), but according to the weak expert it is B. In an informative voting equilibrium, each of them would vote according to their true posteriors. But if the voting rule requires unanimity for decision A to pass, it shall not be passed as the committee decision. This hampers aggregate welfare, because even though the weak expert has voted informatively, the quality of information at his disposal is low owing to his mediocre talents. Hence in order to maximise aggregate welfare under unanimous committees, informative voting is not the criterion to be considered and we require, in this case, the weak expert to exhibit non-conformist tendencies (or anti-herd). The fact that this is the case no matter what is the transparency probability p and the prior π even when ex-ante all experts are identically distributed on the talent interval $[1/2, 1]$ is on the other hand a striking conclusion.

When π is low, the welfare maximising choice would be to have as much transparency as possible to push for non-conformism, thereby minimising the inherent inefficiency embedded in the unanimity rule just discussed. On the other hand, when π is high, welfare maximisation warrants minimising the chance of overturning the committee decision in favour of the unconventional state, which under unanimity is maximised under full secrecy ($p = 0$).

As mentioned before, expert advice becomes most important for the society when the prior is hardly informative so that the public or the decision maker needs expert recommendation to decide which action to take. Part (3) of Proposition 2 shows that when the prior is low, a fully transparent committee using the simple majority rule is better in terms of aggregate welfare than any unanimous committee. This is due to the fact that the simple majority rule does not suffer from any bias in favour of either choices, whereas the unanimity rule is inherently biased in favour of the conventional choice B. This inherent aggregation bias reduces the level of welfare under unanimity for all sorts of randomness of unanimous committees and can be beaten by an appropriate majoritarian committee when the prior is sufficiently low. Hence even under full transparency ($p = 1$), welfare achieved under unanimity is less than that that under majority. This result is in line with what is shown in Fedderson and Pesendorfer (1998) in the context of strategic juries.

The following Corollary draws on the implications of Proposition 1 and Proposition 2.

Corollary 1. Informative Voting and Aggregate Welfare Maximisation through committee decisions are mutually exclusive objectives if experts care about their individual reputations, know their own expertise and have private information in independent spheres of expertise.

3.5 Correlated Signals

We now discuss briefly how the results are likely to change if the dimensions are informationally correlated. If this correlation is low enough (in the extreme case tending to zero), then our results should hold. But suppose there is a high degree of correlation among the dimensions. Take the example of $x = 3$. Then the pivotal expert receiving the signal $s_i = a$ and deciding to vote for B knows that the other two must have voted in favour of outcome A. Due to the high degree of inter-dimensional correlation, he may take this as evidence in favour of the true state in his dimension being a as well. Since the reputation gained by making the correct recommendation is higher, he is more inclined to vote in favour of the unconventional choice A. This may be termed as the pivotality effect. Moreover the fact that the reputation gained by correctly predicting the unconventional choice is higher than that for the conventional choice B is still true. Thus, the intensity of the bias in our model which prompts the mediocre experts to favour voting for the conventional choice B when $x = 3$ gets weakened in this set-up due to the existence of the additional pivotality effect. Hence if the dimensions are highly correlated, informative voting will either not be achievable or the required range of priors to do so will shrink (for example, $\tilde{\pi}$ as in Proposition 1 falls). Note that the extra pivotality effect is absent when $x = 2$. Hence when $x = 2$, the impossibility result that informative voting is not implementable should hold even when the dimensions are correlated. Now we consider aggregate welfare. Since a distorting pivotality effect exists only when $x = 3$, our result that for sufficiently low values of the prior, $x = 2$ promotes higher welfare than $x = 3$ should hold in the case of correlated dimensions as well.

3.6 Summary and Possible Extensions

In the model described in Chapter 3, the objective was to examine the direction and magnitude of influence that random transparency might have on the informativeness of expert advice and welfare from expert committee decisions when the experts are motivated by their private career concerns. We find that for informative voting to be obtained as an equilibrium outcome, it is necessary and sufficient to have the following: a unanimous committee, probabilistic transparency (which is neither too high nor too low), and a prior that is not too informative. It follows then that the simple majority rule is never good for the objective of informative voting. However we then show that even if there exist such unanimous committees with intermediate probabilities of transparencies to achieve informative voting, they can never maximise aggregate welfare, that is, informative voting and maximising aggregate welfare are mutually exclusive virtues for professional committees. We next show that within the class of unanimous committees, randomness of transparency is also never socially desirable. In particular there exists a critical value of the common prior such that if the prior falls below that level, unanimous committees serve the society best in this respect only under full transparency while for priors above that level, full secrecy is desired. Hence when committee decisions are taken unanimously, the presence of whistle blowers and organisations like the Wikileaks which introduces probabilistic transparency can be socially harmful. Finally we show that if the common prior is small (the only case where informative voting is at all attainable), the majority rule is most promising for welfare.

We have been unable to prove analytically some other conjectures that came out of numerical simulations and we now report them briefly. First, we have observed that in Proposition 2, $\pi^* = \pi^{**}$. This means that for unanimous committees there exists a unique threshold level of the prior π^* such that for all priors below (above) π^*, full transparency (secrecy) maximises aggregate welfare. Second, when the prior π is high enough, a fully secretive ($p = 0$) unanimous committee yields a higher welfare than any majoritarian committee (which is an additional observation concerning Part (3) in Proposition 2). Also, if we solely focus on the degree of non-informativeness (that is the absolute difference of the cut-off posterior probability $v(t^*(x, p; \pi), \pi|a)$ from $\frac{1}{2}$), one can observe that under certain conditions, the majoritarian committee is less distortionary than its unanimous counterpart. In particular, the following holds: there exist priors $\pi', \hat{\pi}$ with $0 < \pi' \leq \hat{\pi} < \tilde{\pi} < 1$ such that (1) $\forall \pi > \hat{\pi}$, the degree of non-informativeness under unanimity is lesser than that under simple majority; moreover, a fully secretive ($p = 0$) unanimous committee is the least non-informative one for all $\pi \geq \tilde{\pi}$. (2) $\forall \pi < \pi'$, there exists a unique transparency probability p_π with $0 < p_\pi < 1$ such that (a) $\forall p < p_\pi$, the degree of non-informativeness is lesser under a majoritarian committee, while (b) $\forall p > p_\pi$, it is lesser under a unanimous committees.

There are a number of extensions which may be looked into in this framework. For example, it will be interesting to investigate how the results on informative voting and welfare will change if the number of experts is increased from three. Studying the 3-expert case has allowed us to look at an unbiased aggregation rule (simple majority), and a biased aggregation rule (A-unanimity). However, increasing the number of experts will provide the opportunity to study the impact of super-majority rules as well. We have one conjecture for a specific aggregation rule in this regard. As an illustration, let us consider the number of experts to be a hundred. Suppose the A-unanimity aggregation rule is considered such that the committee decision will be A only if all the hundred experts vote a, and will be B otherwise. In this case, if the pivotal expert with mediocre talent level votes b, the decision will be B, and it will be much more difficult for the public to ascertain what he has personally voted for than in the three-expert case. Hence the incentive for the mediocre expert to be a conformist and vote in favour of the conventional choice in order to disguise his personal vote from the public gets stronger as the number of committee members increases. Therefore, the degree of leakage optimally required to elicit informative voting should increase. We may also consider a scenario where the experts care explicitly for welfare and are not solely driven by career concerns. If the aggregate welfare function explicitly enters the pay-off function of the expert, then his incentive to vote for the conventional choice b will rise as the prior increases and vice versa. Also, we may consider an endogenous model of leakage where individual committee members may choose to reveal their personal recommendations to the public. It would be interesting to know whether endogeneity of leakage can lead to leakage at all and if so which types of experts would be more inclined to do so. Further, one may also model exogenous leakage institutions in greater detail to understand the different objectives which lead to varying degrees of transparency and whether the design of committees itself can control this exogenous randomness. One may also ask if our results hold in a scenario wherein private information transmission is allowed among experts through deliberation and how randomness affect the value of information flow across experts. We reserve these extensions for future research.

3.7 Chapter Appendix

We divide the Appendix containing the proofs of the results described in this chapter into two parts. The main proofs of Propositions 1 and 2 are in Appendix 1. Thes proofs require us to prove some further sub-results which we move to Appendix 2 to maintain a smoother presentation of the main proofs. The proofs described in Appendix 2 are contained in Levy (2007a).

3.7.1 Appendix 1

Proof of Proposition 1: We begin with the posterior beliefs of the experts. Using Bayes rule, the posterior belief $v(\pi, t_i)$ of expert i is given by

$$v(\pi, t_i|s_i) := \Pr(w_i = a|\pi, s_i, t_i) = \begin{cases} \frac{(1-\pi)(1-t_i)}{\pi t_i + (1-\pi)(1-t_i)} \text{ if } s_i = b \\ \frac{(1-\pi)t_i}{\pi(1-t_i)+(1-\pi)t_i} \text{ if } s_i = a. \end{cases}$$

Given the definition of informative voting, and the expression for the posterior $v(\pi, t_i|a)$ as given above, we begin with the following observation, the proof of which is straightforward.

Observation 1. *When $s_i = a$, then $v(\pi, t_i|a) \leq 1/2$ iff $t_i \leq \pi$. Hence, if expert i is using an informative voting strategy, then the following must be true: when $s_i = a$, we have $t(x, p; \pi) = \pi$.*

Notice the fixed-point element (viz. for π) in the requirement of informative voting. The existence of this fixed point feature will be central in the remainder of the proof.

From Observation 1 we know that $\mathcal{C} = (x, p)$ is informative if and only if $t^*(x, p; \pi) = \pi$, where '$*$' is used to indicate equilibrium. Also, as the proposed class of voting strategy is state reflective, it follows that in equilibrium, $m_i = a$ only if $s_i = a$ and $t_i > t^*(x, p; \pi)$. Thus,

$$\mu_a = \mathbf{Pr}[s_i = a \text{ and } t_i > t^*(x, p; \pi) | w_i = a, t_i, \zeta^*].$$

But

$$\mathbf{Pr}[s_i = a \text{ and } t_i > t^*(x, p; \pi) | w_i = a, t_i, \zeta^*] = \begin{cases} t_i \text{ if } t_i > t^*(x, p; \pi) \\ \quad 0 \text{ otherwise} \end{cases}$$

Hence

$$\mu_a = \int_{t^*(x,p;\pi)}^{1} t_i f(t_i) dt_i = 1 - t^*(x, p; \pi)^2,$$

where $f(\cdot)$ stands for the uniform prior over T. Since the equilibrium is informative, it follows that $\mu_a = 1 - \pi^2$.

Similarly we have

$$\mu_b = \mathbf{Pr}[s_i = a \text{ and } t_i > t^*(x, p; \pi) | w_i = b, t_i, \zeta^*].$$

But

$$\mathbf{Pr}[s_i = a \text{ and } t_i > t^*(x, p; \pi) | w_i = b, t_i, \zeta^*] = \begin{cases} 1 - t_i \text{ if } t_i > t^*(x, p; \pi) \\ \quad 0 \quad \text{otherwise.} \end{cases}$$

Hence

$$\mu_b = \int_{t^*(x,p;\pi)}^{1} (1 - t_i) f(t_i) dt_i. = (1 - t^*(x, p; \pi))^2,$$

and so, since the equilibrium is informative, we have $\mu_b = (1 - \pi)^2$.

Let

$$\pi_{w_i}(x, t^*(x, p; \pi)) = \Pr[d_x = A | m_i = w_i, \{w_j\}_{j \neq i}, t^*(x, p; \pi)],$$

and recall that $\alpha_{d_x}(w_i, \{w_j\}_{j\neq i}, x)$ is the public's posterior belief that $m_i = a$, given that the public knows now the committee decision d_x and has observed the states in each dimension. Then,

$$\alpha_A(w_i, \{w_j\}_{j\neq i}, x) = \frac{\mu_{w_i}\pi_a(x, t^*(x,p;\pi))}{\mu_{w_i}\pi_a(x, t^*(x,p;\pi)) + (1-\mu_{w_i})\pi_b(x, t^*(x,p;\pi))},$$

$$\alpha_B(w_i, \{w_j\}_{j\neq i}, x) = \frac{\mu_{w_i}(1-\pi_a(x, t^*(x,p;\pi)))}{\mu_{w_i}(1-\pi_a(x, t^*(x,p;\pi))) + (1-\mu_{w_i})(1-\pi_b(x, t^*(x,p;\pi)))}.$$

Finally define $\alpha(d_x, w_i, x)$ to be the probability estimate *held by expert* i of the public's posterior belief that $m_i = a$.

$$\alpha(d_x; w_i, x) = \sum_{(w_j,w_k)\in\{a,b\}^2} \Pr[(w_j, w_k)|\mathbf{piv}_i, x, t^*(x,p;\pi)]\alpha_{d_x}(w_i, \{w_j\}_{j\neq i}, x),$$

where $\mathbf{piv}_i$ stands for the event that expert i is pivotal.

Let $U(m_i; p)$ be the expected payoff of expert i with talent t_i and private signal s_i from the vote m_i. Using the shorthand $v := v(\pi, t_i|s_i)$, we have

$$\begin{aligned}
U(a;p) &= p\left[v\tau(a,a,\zeta^*) + (1-v)\,\tau(a,b,\zeta^*)\right] \\
&+ (1-p)\left[v\left(\alpha(A,a,x)\tau(a,a,\zeta^*) + (1-\alpha(A,a,x))\tau(b,a,\zeta^*)\right)\right. \\
&+ \left.(1-v)\left(\alpha(A,b,x)\tau(a,b,\zeta^*) + (1-\alpha(A,b,x))\tau(b,b,\zeta^*)\right)\right],
\end{aligned}$$

and

$$\begin{aligned}
U(b;p) &= p[v\tau(b,a,\zeta^*) + (1-v)\tau(b,b,\zeta^*)] \\
&+ (1-p)[v\left(\alpha(B,a,x)\tau(a,a,\zeta^*) + (1-\alpha(B,a,x))\tau(b,a,\zeta^*)\right) \\
&+ (1-v)\left(\alpha(B,b,x)\tau(a,b,\zeta^*) + (1-\alpha(B,b,x))\tau(b,b,\zeta^*)\right)]
\end{aligned}$$

Case A: $s_i = b$. The following lemma shows that the cut-off strategy is consistent with equilibrium behaviour in every subgame where player i receives the signal $s_i = b$ for any $p \in [0,1]$. Moreover, in each such subgame, voting is informative irrespective of the actual realization of the random variable t_i.

Lemma 1. *If $s_i = b$, then for any value of t_i, any transparency probability $p \in [0,1]$ and any voting rule $x \in \{2,3\}$, we have (i) $v < 1/2$ and (ii) $m_i = b$ is expert i's best response for all talent levels. Hence voting is informative.*

Proof. The following has already been shown in Levy (2004, 2007a): if $s_i = b$, then expert i with any t_i is strictly better off with $m_i = b$ in any committee $C = (x,p)$ as long as $p \in \{0,1\}$.[15] Since the expected payoff for an expert in the committee $C = (x,p)$ for any $p \in (0,1)$ is a convex combination of these payoffs, this proves part (ii). To prove part (i) observe that $v(\pi, t_i|b) < 1/2$ if and only if $1 - t_i < \pi$. But since $t_i \geq 1/2$ and $\pi > 1/2$, this condition must always hold. Parts (i) and (ii) together then imply that in each subgame with $s_i = b$, voting is informative irrespective of the actual realization of the random variable t_i. $\square$

The intuition behind Lemma 1 is the following: the reputation gained by making a correct prediction is always greater than the reputation gained by making an incorrect prediction. Since according to the informative prior the likelier correct state is b, if the private informative signal received by the expert is also b, then she has no reason to go against both these informative sources and send a message of $m_i = a$.

Given Lemma 1, it is enough to consider the case when $s_i = a$. Hence, the rest of the proof deals with that case.

Case B: $s_i = a$. Consider the indifference equation $U(a;p) = U(b;p)$. We know from Observation 1 that if an expert votes informatively, then upon receiving a private signal $s_i = a$, she will be indifferent between $m_i = a$ and $m_i = b$ only when her talent $t_i = \pi$. Let $v^* \equiv v(\pi, \pi|a)$ and $\hat{\tau}(m_i, w_i; \zeta)$ be the evaluation when $t^*(x,p;\pi) = \pi$. Note that $v(t^*(x,p;\pi), \pi|a) = 1/2$.

[15] The outline of the proof is provided as Proof A in the Appendix 2.

Let $p(\pi)$ solve the indifference equation $U(a,p) = U(b,p)$ for the case when $t^*(x,p;\pi) = \pi$. The strategy of the rest of the proof is as follows. We shall show that such a solution never exists when $x = 2$ and exists under certain restrictions when $x = 3$. We proceed as follows.

Suppose $p(\pi)$ exists. Then,

$$p(\pi) := \frac{N}{N - M},$$

where

$$M := v^*(\hat{\tau}(b,a;\zeta) - \hat{\tau}(a,a;\zeta)) + (1 - v^*)(\hat{\tau}(b,b;\zeta) - \hat{\tau}(a,b;\zeta)),$$

and

$$\begin{aligned} N :=& v^*(\alpha(A;a,x) - \alpha(B;a,x))(\hat{\tau}(b,a;\zeta) - \hat{\tau}(a,a;\zeta)) \\ &+ (1 - v^*)(\alpha(A;b,x) - \alpha(B;b,x))(\hat{\tau}(b,b;\zeta) - \hat{\tau}(a,b;\zeta)). \end{aligned}$$

Note that the expressions for M and N depend only on the prior π and their reduced forms, both for $x = 3$ and $x = 2$, are given in Appendix 2 and are used in the rest of the proof.

For existence of $p(\pi)$, it is necessary that $p(\pi) \geq 0$. For $p(\pi) \geq 0$, there are two exclusive necessary and sufficient conditions: either (I) $[N \geq 0$ and $N > M]$ or (II) $[N \leq 0$ and $N < M]$.

Suppose condition (I) holds. As it is also necessary that $p(\pi) \leq 1$, it then follows that $N \leq N - M$ so that $M \leq 0$. On the other hand if condition (II) holds, then by similar arguments it must be that $M \geq 0$.

Claim 1. *For all committees $C = (x,p)$ and for all prior $\pi \in (1/2, 1)$, we have $M < 0$.*

Proof. Since $v^* = 1/2$, it follows that $M < 0$ if and only if

$$\hat{\tau}(b,a;\zeta) + \hat{\tau}(b,b;\zeta) < \hat{\tau}(a,b;\zeta) + \hat{\tau}(a,a;\zeta),$$

a condition that always holds given the inequalities (iii) and (iv) in Proof A in Appendix 2. $\square$

Claim 1 rules out condition (II) and for the rest of the proof we shall only consider condition (I).

We now give a direct proof of Part (i) of the proposition. So let $x = 2$. It is routine to verify that if $\pi \in \{1/2, 1\}$, then $N < 0$. Next, setting $N = 0$ and solving for π yields a unique real root $\pi \approx -0.2208 \notin [1/2, 1]$. Since N is continuous in π, we conclude that for all $\pi \in [1/2, 1]$ it must be that $N < 0$. Thus we have shown that with $x = 2$, condition (I) can never be satisfied. This proves part (i).

We now prove part (ii) of the proposition. Suppose $x = 3$. It is again routine to check the following: at $\pi = 1/2$ we have $N > 0$; at $\pi = 1$ we have $N < 0$; and $N = 0$ if and only if $\pi = \tilde{\pi}(\approx 0.54197)$. Given these, the rest of the proof follows by invoking the fact that N is continuous in π. This completes the proof of the proposition.

Proof of Proposition 2: The following lemma will be useful in the proof of Proposition 2.

Lemma 2. *Suppose $t^*(x, p; \pi) \in [1/2, 1]$ solves the indifference equation $U(a; p) = U(b; p)$. Then $t^*(x, p; \pi) > t^*(x, p'; \pi)$ if and only if $p < p'$.*

Proof. By suitable manipulation, the indifference equation $U(a, p) = U(b, p)$ can be expressed as $pL = (1 - p)R$, where $L = U(a; 1) - U(b; 1)$ and $R = U(b, 0) - U(a, 0)$. Levy (2004 and 2007a) shows that for $x = \{2, 3\}$, the following hold:[16] $\frac{\mathrm{d}L}{\mathrm{d}t} > 0$ and $\frac{\mathrm{d}R}{\mathrm{d}t} < 0$.

Now consider the cut-off talent level $t^*(x, p; \pi)$ that solves the indifference equation $U(a; p) = U(b; p)$. Fix the value of $t^*(x, p; \pi)$ thus obtained and suppose p rises to p' so that now $p'L > (1 - p')R$. Let $t^*(x, p'; \pi)$ be the new cut-off talent that solves the

[16] The outline of the proofs of these two inequalities are given in Proof B in Appendix 2.

indifference equation $p'L = (1-p')R$. The equality $p'L = (1-p')R$ can be attained in one of the following three ways: either (i) L decreases and R increases, or (ii) both L and R fall but the fall in L is larger than that in R, or (iii) both L and R rise but the rise in L is smaller than that in R. But since $\frac{\mathrm{d}L}{\mathrm{d}t} > 0$ and $\frac{\mathrm{d}R}{\mathrm{d}t} < 0$, cases (ii) and (iii) cannot be true as in each of these two cases the required directions of $t^*(\cdot)$ are opposite to each other. Hence it must be that case (i) holds. But for that case it must be that $t^*(\cdot)$ falls. To complete the proof, we address the special situation where the equation $U(a,p) = U(b,p)$ is solved at $t^*(x,p;\pi) = 1/2$. For that case we can mimic the above proof by considering $p'' < p$ for which $p''L < (1-p'')R$ and then similarly show that $t^*(x,p'';\pi) > t^*(x,p;\pi)$. □

Lemma 2 shows that as the probability of the committee being transparent rises, the cut-off talent t^* falls. Given that all experts with talents above t^* vote $m_i = a$, the lemma suggests that as the committee gets 'more' transparent, non-conformist tendencies (that is voting against the direction of the common prior) rise.[17] It is also important to note that although the proof of the lemma uses a 'convexification' argument on two extreme committees, namely, $C(x,0)$ with weight $1-p$ and $C(x,1)$ with weight p, the cut-off talent $t^*(x,p;\pi)$ is not in general equal to $pt^*(x,1;\pi) + (1-p)t^*(x,0;\pi)$.

Keeping this in mind, we now return to the proof of Proposition 2.

Let $x = 3$. Fix p and π and use the shorthand $t := t^*(3,p;\pi)$ for the cut-off talent in

[17] In Levy's (2007a) special cases of $p \in \{0,1\}$ it was shown that $t^*(3,1;\pi) < t^*(3,0;\pi)$ and for high enough values of π, we have $t^*(2,1;\pi) < t^*(2,0;\pi)$.

equilibrium. Then,

$$\begin{aligned}W(3,p,\pi) =&\pi^3(((1-t)^2)^3(3\beta)+(1-((1-t)^2)^3)(3\alpha))+(1-\pi)^3((1-t^2)^3(3\alpha)+\\&(1-(1-t^2)^3)(3\beta))+3(1-\pi)^2\pi(((1-t^2)^2(1-t)^2)(2\alpha+\beta)+\\&(1-(1-t^2)^2(1-t)^2)(2\beta+\alpha))+3\pi^2(1-\pi)((((1-t)^2)^2(1-t^2))(2\beta+\alpha)+\\&(1-((1-t)^2)^2(1-t^2))(2\alpha+\beta))\end{aligned}$$

Maximise $W(x,p,\pi)$ with respect to t. Let t^f be the *free* solution from the first order condition of unconstrained optimisation of $W(C(x,p),\pi)$, given by $\frac{\mathrm{d}W}{\mathrm{d}t}=0$ Then, t_f is given by the following three solutions: $t_1^f=\frac{1}{2\pi-1}$, $t_2^f=\frac{A+10\pi^2-7\pi+3}{6(2\pi-1)}$, and $t_3^f=\frac{A-10\pi^2+7\pi-3}{6(1-2\pi)}$, where $A=(100\pi^2-36\pi+9)^{1/2}|\pi-1|$. Let t^* be the constrained solution so that $t^*\in[1/2,1]$ by definition.

To prove Part (1) we proceed as follows. Observe that since $0<t<1$, it suffices to check if there exists π such that $t^*=\pi$ from any of the above solutions. Inserting $t_k^f=\pi, k=1,2,3$, it is routine to check that for the first two solutions, viz. t_1^f and t_2^f, this implies $\pi=1$. For the remaining solution t_3^f, we have $\pi=1$ or $\pi=0$. But since $\pi\in(1/2,1)$, this proves that informative voting cannot be a solution to the aggregate welfare maximisation problem.

To prove Part (2.a) we proceed as follows. Define the function $S(t)=4t^3-9t^2+6t-1$. Note that $\frac{\mathrm{d}W}{\mathrm{d}t}|_{\pi=1/2}=-3(\alpha-\beta)S(t)$. We first show that $S(t)>0$ for all $t\in[1/2,1]$. For that, by invoking the fact that $S(t)$ is a continuous function, it is sufficient to observe that $S'(t)=0$ has exactly two solutions, $t=1/2$ and $t=1$, $S(1)=0$ and $S(1/2)=0.25>0$. Since $\alpha>\beta$, it then follows that $\frac{\mathrm{d}W}{\mathrm{d}t}|_{\pi=1/2}<0$ for all values of t. By continuity of $W(\cdot)$ in π, it follows that there exists $1/2<\pi^*<1$ such that for each $\pi\leq\pi^*$, we have $\frac{\mathrm{d}W}{\mathrm{d}t}<0$ for all values of t. Thus for such values of π, it must be that $t^{**}=1/2$. Now recall the definition of $t^*(3,p;\pi)$ that solves the indifference equation $U(a;p) = U(b;p)$. By Lemma 2, it follows that for each $\pi \leq \pi^*$, $p = 1$ uniquely maximises $W(x,p,\pi)$.

We prove Part (2.b) in a similar fashion. Define the function $H(t) = t^5 - 5t^4 + 10t^3 - 10t^2 + 5t - 1$. Note that $\frac{\mathrm{d}W}{\mathrm{d}t}|_{\pi=1} = -18(\alpha - \beta)H(t)$. We first show that $H(t) < 0$ for all $t \in [1/2, 1)$. This is established by the following facts that can be easily checked: $H'(t) = 0$ has a unique real root $t = 1$, $H'(1/2) = 5/16 > 0$, $H(1/2) = -1/32 < 0$ and $H(1) = 0$. Hence by continuity of $H(\cdot)$ and the fact that $\alpha > \beta$, it follows that $H(t) < 0$ for all $t \in [1/2, 1)$. By continuity of $W(\cdot)$ in π, it follows that there exists $\pi^{**} < 1$ such that for each $\pi \geq \pi^{**}$, we have $\frac{\mathrm{d}W}{\mathrm{d}t} > 0$ for all values of $t \in [1/2, 1)$. We now use the following fact that follows from Levy (2004).[18]

Fact 1. *For every π, there exists $1/2 \leq \bar{t}(\pi) < 1$ such that $t^*(x,p;\pi) \leq \bar{t}(\pi)$ for all p.*

Given Fact 1, for each $\pi \geq \pi^{**}$, it must be that $t^{**} = \bar{t}(\pi)$. By Lemma 2 it follows that for each $\pi \geq \pi^{**}$, the value of p which maximises $W(C(x,p);\pi)$ is $p = 0$.

We now prove part (3). Given what we have proved thus far, it would suffice to show that there exists a threshold value $\hat{\pi}$ of the prior with $1/2 < \hat{\pi} < 1$ such that for all $\pi < \hat{\pi}$ and for all $\alpha, \beta \in \mathbf{R}$, $\alpha > \beta$, we have $W(C(2,1),\pi) > W(C(3,1),\pi)$. We first prove the following claim.

Claim 2. $t^*(x,p;\pi) = 1/2$ *when* $p = 1$ *and* $\pi = 1/2$.

Proof. Recall the indifference equation $pL = (1-p)R$ used in the proof of Lemma 2. At $p = 1$ this indifference equation is solved if and only if $L = 0$, where $L = U(a;1) - U(b;1)$. From the expressions of $\tau(m_i, w_i; \zeta)$ it follows that at $t^*(x,p;\pi) = 1/2$, we have $\tau(a,a;\zeta) = \tau(b,b;\zeta)$ and $\tau(b,a;\zeta) = \tau(a,b;\zeta)$. Using these, one can obtain $L =$

[18] The outline of the proof is given as Proof C in Appendix 2.

$(1-2v)\left(\tau(a,a;\zeta)-\tau(b,a;\zeta)\right)$. From inequalities (i)-(iv) in Proof A in Appendix 2 it follows that $\tau(a,a;\zeta) > \tau(b,a;\zeta)$. Hence $L = 0$ if and only if that $v = 1/2$ which is possible at $\pi = 1/2$ if and only if $t^*(x,1;1/2) = 1/2$. $\square$

Let $x = 2$. The full expression for $W(2,p,\pi)$ is provided in Appendix 2. That expression, using the shorthand $t := t(x,p;\pi)$, simplifies to

$$\begin{aligned}W(2,p,\pi) =& 3(\beta(8\pi^3t^2(2t^3-5t^2+4t-1)-\\ & 4\pi^2t^2(2t^4-5t^2+2t+1)+\pi(8t^6-4t^5-10t^4+4t^3+1)-\\ & t^4(2t^2-3))-\alpha(8\pi^3t^2(2t^3-5t^2+4t-1)-\\ & 4\pi^2t^2(2t^4-5t^2+2t+1)+\pi(8t^6-4t^5-10t^4+4t^3+1)\\ & -(t^2-1)^2(2t^2+1)))\end{aligned}$$

It follows that at $p = 1$ and $\pi = 1/2$, we have $W(2,1,1/2) = \frac{6}{16}(5\alpha+3\beta)$. From part (2) we know that when $\pi < \pi^*$ (where π^* is as defined there), aggregate welfare under $x = 3$ is maximised if and only if $p = 1$. So consider $\pi = 1/2$, $p = 1$ and $x = 3$. Then, $W(3,1,1/2) = \frac{3}{16}(9\alpha+7\beta)$. Note that since $\alpha > \beta$ it follows that $W(2,1,1/2) > W(3,1,1/2)$. By continuity of $W(\cdot)$ in π, there exists $\hat{\pi} > 1/2$ such that fixing $t = 1/2$, we have $W(2,1,\pi) > W(3,1,\pi)$ for all $\pi < \hat{\pi}$. Using the expressions for aggregate welfare above, it is routine to show that

$$\frac{\mathrm{d}W(x,p,\pi)}{\mathrm{d}t}\Big|_{x=3,\pi=t=1/2} = \frac{3}{4}(\beta-\alpha) < 0,$$

and

$$\frac{\mathrm{d}W(x,p,\pi)}{\mathrm{d}t}\Big|_{x=2,\pi=t=1/2} = 0,$$

and

$$\frac{\mathrm{d}^2W(x,p,\pi)}{\mathrm{d}t^2}\Big|_{x=2,\pi=t=1/2} = 6(\beta-\alpha) < 0.$$

Proposition 1 in Levy (2004) shows that $\frac{\mathrm{d}t^*(\cdot)}{\mathrm{d}\pi} > 0$ for all $x \in \{2, 3\}$ when $p = 1$.[19] Hence, as π rises from $\pi = 1/2$, the cut-off talent t^* rises for both $x = 2$ and $x = 3$, and so in equilibrium, the desired inequality $W(2, 1, \pi) > W(3, 1, \pi)$ is sustained for all $\pi < \hat{\pi}$.

This completes the proof of Proposition 2.

3.7.2 Appendix 2

Expressions for $\tau(m_i, w_i; \zeta)$: Using the class of strategies defined earlier, we first need to work out the specific forms of the evaluation functions as follows:

$$\tau(a, a; \zeta^*) = \mathbf{E}(t_i|m_i = a, w_i = a, \zeta^*) = \int_{\frac{1}{2}}^{1} t_i f(t_i|m_i = a, w_i = a, \zeta_i^*)\mathrm{d}t_i,$$

where,

$$f(t_i|m_i = a, w_i = a, \zeta^*) = \frac{\Pr[(m_i = a|w_i = a, \zeta^*)|t_i]. \Pr(t_i)}{\int_{\frac{1}{2}}^{1} \Pr[(m_i = a|w_i = a, \zeta^*)|t_i] \cdot \Pr(t_i)\mathrm{d}t_i}.$$

Now,

$$\begin{aligned} \Pr[(m_i &= a|w_i = a, \zeta^*)|t_i]. \Pr(t_i) = \Pr[s_i = a \text{ and } t_i > t^*(x, p; \pi)|w_i = a, t_i]. \Pr(t_i) \\ &= \begin{cases} 0 \text{ if } t_i \leq t^*(x, p; \pi) \\ t_i f(t_i) \text{ otherwise.} \end{cases} \end{aligned}$$

So

$$f(t_i|m_i = a, w_i = a, \zeta^*) = \begin{cases} \frac{t_i f(t_i)}{\int_{t^*(x,p;\pi)}^{1} t_i f(t_i)\mathrm{d}t_i} & \text{if } t_i > t^*(x, p; \pi) \\ 0 \text{ otherwise.} \end{cases}$$

Hence,

$$\tau(a, a; \zeta^*) = \int_{t^*(x,p;\pi)}^{1} t_i \frac{t_i f(t_i)}{\int_{t^*(x,p;\pi)}^{1} t_i f(t_i)\mathrm{d}t_i} \mathrm{d}t_i.$$

Similarly one obtains

$$\tau(a, b; \zeta^*) = \int_{t^*(x,p;\pi)}^{1} t_i \frac{(1 - t_i) f(t_i)}{\int_{t^*(x,p;\pi)}^{1} (1 - t_i) f(t_i)\mathrm{d}t_i} \mathrm{d}t_i,$$

[19] The outline of the proof is given in Proof D in Appendix 2.

$$\tau(b,b;\zeta^*) = \int_{\frac{1}{2}}^{t^*(x,p;\pi)} t_i \frac{f(t_i)}{\int_{\frac{1}{2}}^{t^*(x,p;\pi)} f(t_i)\mathrm{d}t_i + \int_{t^*(x,p;\pi)}^{1} t_i f(t_i)\mathrm{d}t_i} \mathrm{d}t_i +$$
$$\int_{t^*(x,p;\pi)}^{1} t_i \frac{t_i f(t_i)}{\int_{\frac{1}{2}}^{t^*(x,p;\pi)} f(t_i)\mathrm{d}t_i + \int_{t^*(x,p;\pi)}^{1} t_i f(t_i)\mathrm{d}t_i} \mathrm{d}t_i,$$

and

$$\tau(b,a;\zeta^*) = \int_{\frac{1}{2}}^{t^*(x,p;\pi)} t_i \frac{f(t_i)}{\int_{\frac{1}{2}}^{t^*(x,p;\pi)} f(t_i)\mathrm{d}t_i + \int_{t^*(x,p;\pi)}^{1} (1-t_i) f(t_i)\mathrm{d}t_i} \mathrm{d}t_i +$$
$$\int_{t^*(x,p;\pi)}^{1} t_i \frac{(1-t_i) f(t_i)}{\int_{\frac{1}{2}}^{t(x,p;\pi)} f(t_i)\mathrm{d}t_i + \int_{t^*(x,p;\pi)}^{1} (1-t_i) f(t_i)\mathrm{d}t_i} \mathrm{d}t_i.$$

Expressions for M,N used in the proof of Proposition 1

Suppose voting is informative, that is $t(x,p;\pi) = \pi$. Then the term M is the same for both $x = 3$ and $x = 2$ and is given by

$$M = \frac{10\pi^2 - 3\pi - 1}{12\pi^2(\pi+1)(\pi-2)}.$$

For $x = 3$, the term N is given by $N = \frac{K}{Q}$, where

$$\begin{aligned} K =& 8\pi^{24} - 89\pi^{23} + 394\pi^{22} - 757\pi^{21} - 78\pi^{20} + \\ & 3239\pi^{19} - 5391\pi^{18} - 557\pi^{17} + 12635\pi^{16} - 13656\pi^{15} - \\ & 5570\pi^{14} + 23501\pi^{13} - 14031\pi^{12} - 11173\pi^{11} + 18614\pi^{10} - \\ & 3994\pi^{9} - 7283\pi^{8} + 3435\pi^{7} + 2361\pi^{6} - 374\pi^{5} - \\ & 2556\pi^{4} + 798\pi^{3} + 974\pi^{2} - 348\pi - 48, \end{aligned}$$

and

$$\begin{aligned} Q =& 12\pi^2(\pi+1)(2-\pi)(\pi^3 - 2\pi^2 + 2)(\pi^4 - 3\pi^2 + 3)\times \\ & (\pi^4 - 4\pi^3 + 7\pi^2 - 6\pi + 3)(\pi^5 - 2\pi^4 - \pi^3 + 4\pi^2 - \pi - 2)\times \\ & (\pi^5 - 4\pi^4 + 5\pi^3 - 5\pi + 4)(4\pi^2 + 4\pi + 1). \end{aligned}$$

For $x = 2$, the term N is given by $\frac{F}{Z}$, where

$$\begin{aligned} F =& 2048\pi^{21} - 19712\pi^{20} + 73472\pi^{19} - 115264\pi^{18} - \\ & 11456\pi^{17} + 311616\pi^{16} - 402624\pi^{15} + 11216\pi^{14} + \\ & 448432\pi^{13} - 419904\pi^{12} + 35584\pi^{11} + 172004\pi^{10} - 81524\pi^{9} + \\ & 1108\pi^{8} - 40588\pi^{7} + 38987\pi^{6} + 8909\pi^{5} - 11209\pi^{4} - \\ & 185\pi^{3} - 1614\pi^{2} + 80\pi + 120. \end{aligned}$$

and

$$\begin{aligned} Z =& 12\pi^2(\pi + 1)(\pi - 2)(2\pi^2 + 1)(2\pi^2 - 3)(2\pi^2 - 4\pi - 1)\times \\ & (2\pi^2 - 4\pi + 3)(4\pi^2 - 4\pi - 3)(2\pi^3 - 2\pi^2 - \pi - 1)\times \\ & (2\pi^3 - 2\pi^2 - 3\pi - 1)(2\pi^3 - 4\pi^2 + \pi + 2)(2\pi^3 - 4\pi^2 - \pi + 4). \end{aligned}$$

Full expression for Aggregate Welfare for $x = 2$: Using the shorthand $t := t(x, p; \pi)$, we have

$$
\begin{aligned}
W(C(2,p),\pi) =&(1-\pi)^3(((1-t^2)^3+3(1-t^2)^2(1-(1-t^2)))(3\alpha)+\\
&(1-((1-t^2)^3+3(1-t^2)^2(1-(1-t^2))))(3\beta))+\\
&(3\pi(1-\pi)^2)(((1-t^2)^2(1-t)^2+(1-t^2)^2(1-(1-t)^2)+\\
&2(1-t^2)(1-t)^2(1-(1-t^2)))(2\alpha+\beta)+(1-((1-t^2)^2(1-t)^2+\\
&(1-t^2)^2(1-(1-t)^2)+2(1-t^2)(1-t)^2(1-(1-t^2))))(2\beta+\alpha))+\\
&(3(1-\pi)\pi^2)(((1-t^2)((1-t)^2)^2+(1-(1-t^2))((1-t)^2)^2+\\
&2(1-(1-t)^2)(1-t^2)(1-t)^2)(\alpha+2\beta)+(1-((1-t^2)((1-t)^2)^2+\\
&(1-(1-t^2))((1-t)^2)^2+2(1-(1-t)^2)(1-t^2)(1-t)^2))(2\alpha+\beta))+\\
&\pi^3((((1-t)^2)^3+3((1-t)^2)^2(1-(1-t)^2))(3\beta)+(1-(((1-t)^2)^3+\\
&3((1-t)^2)^2(1-(1-t)^2)))(3\alpha)).
\end{aligned}
$$

Proof A: Part a:(provided as Lemma 2 and Lemma 3 in Levy 2004): Consider $p = 1$. In this case the indifference equation $U(a;1) = U(b;1)$ may be written as:

$$
\frac{\tau(a,a,\zeta_i^*)-\tau(b,a,\zeta_i^*)}{\tau(b,b,\zeta_i^*)-\tau(a,b,\zeta_i^*)} = \frac{1-v}{v} \tag{3.1}
$$

where v is as defined in the text.

Using the Maximum Likelihood Ratio Property (MLRP) it is shown that if the indifference equation is solved for $s_i = a$, then the following inequalities hold: (i)$\tau(a,a,\zeta_i^*) > \tau(a,b,\zeta_i^*)$, (ii) $\tau(b,b,\zeta_i^*) > \tau(b,a,\zeta_i^*)$, (iii) $\tau(a,a,\zeta_i^*) > \tau(b,b,\zeta_i^*)$ (iv) $\tau(a,b,\zeta_i^*) > \tau(b,a,\zeta_i^*)$. If the indifference equation is solved for $s_i = b$, then the following inequalities hold: (v)$\tau(a,a,\zeta_i^*) > \tau(a,b,\zeta_i^*)$, (vi) $\tau(b,b,\zeta_i^*) > \tau(b,a,\zeta_i^*)$, (vii) $\tau(b,b,\zeta_i^*) > \tau(a,a,\zeta_i^*)$ (viii) $\tau(b,a,\zeta_i^*) > \tau(a,b,\zeta_i^*)$. Now consider the case of $s_i = b$. Using inequalities (v)-(viii), it follows that the LHS of equation (3.1) is less than 1, while the RHS of equation (3.1) is greater than 1. Hence the LHS $<$ RHS, which may be rewritten as $v\tau(a, a, \zeta_i^*) + (1 - v)\tau(a, b, \zeta_i^*) < (1 - v)\tau(b, b, \zeta_i^*) + v\tau(b, a, \zeta_i^*)$. Note that the LHS is actually the expected gain from $m_i = a$ while the RHS is the expected gain from $m_i = b$. Hence the expert can never be indifferent between $m_i = a$ and $m_i = b$ when $s_i = b$, and the indifference equation can only be satisfied when $s_i = a$. Note further that the RHS of equation (3.1) is an increasing (decreasing) function of t when a private signal of $b(a)$ is received by the expert, while the LHS is a constant. This along with the fact that the RHS is equal for $t = \frac{1}{2}$ for the $s_i = a$ and $s_i = b$ cases imply that when $s_i = b$, then $U(a; 1) < U(b; 1)$.

Proof A: Part b:(provided in Proposition 2 in Levy 2007a): Now consider $p = 0$. Note that due to state reflective voting, the following inequalities hold for any $x = \{2, 3\}$, which are : (ix) $\alpha(A; a, x) \geq \alpha(B; a, x)$, (x) $\alpha(A; b, x) \geq \alpha(B; b, x)$, (xi) $\alpha(A; a, x) \geq \alpha(A; b, x)$, (xii) $\alpha(B; a, x) \geq \alpha(B; b, x)$. Using inequalities (v)-(xii), by suitable manipulation it is shown that $U(a; 0) < U(b; 0)$ for all talent levels when $s_i = b$, and hence the expert can never be indifferent between $m_i = a$ and $m_i = b$ when $s_i = b$. Now consider the case when the indifference equation is solved by $s_i = a$. By suitable manipulation of the indifference equation, and the fact that the expression $(1 - v)/v$ is an increasing (decreasing) function of t when $s = b(a)$, and is equal when $t = \frac{1}{2}$, it follows that in this case, $U(a; 0) < U(b; 0)$.

Proof B: Part a: (provided in Proposition 1 of Levy 2004): Consider $p = 1$. Note that in the case of $s_i = a$, given inequalities (i)-(iv), we have $\frac{\mathrm{d}U(a;p=1)}{dt} > 0$ and $\frac{\mathrm{d}U(b;p=1)}{dt} < 0$. Hence $\frac{\mathrm{d}L}{\mathrm{d}t} > 0$.

Proof B: Part b: (provided in Proposition 2 in Levy 2007a): When $p = 0$, the indifference equation can be re-arranged to be written as

$$v[\alpha(A;a,x)-\alpha(B;a,x)][\tau(a,a,\zeta_i^*)-\tau(b,a,\zeta_i^*)] =$$

$$(1-v)[\alpha(A;b,x)-\alpha(B;b,x)][\tau(b,b,\zeta_i^*)-\tau(a,b,\zeta_i^*)]$$

By inequalities (ix) to (xii), one obtains $[\alpha(A;a,x)-\alpha(B;a,x)] > 0$ and $[\alpha(A;b,x)-\alpha(B;b,x)] > 0$. By differentiating with respect to the cut-off talent level, it is shown that $\frac{\mathrm{d}U(a;p=0)}{dt} > 0$ and $\frac{\mathrm{d}U(b;p=0)}{dt} < 0$. Hence $\frac{\mathrm{d}R}{\mathrm{d}t} < 0$.

Proof C (provided in Proposition 1 in Levy 2004): The main argument is as follows: If the upper bound of the cut-off indifferent talent level is violated, the ranking of the talent evaluation functions become $\tau(a,a,\zeta_i^*) > \tau(a,b,\zeta_i^*) > \tau(b,b,\zeta_i^*) > \tau(b,a,\zeta_i^*)$. This implies that experts of all talent levels receiving any private signal vote $m_i = a$, since this becomes the dominant strategy of all experts and we have a perfectly pooling equilibrium such that the indifference equation never holds and therefore the conjecture ζ_i^* will not be consistent with the actual strategy followed by the expert i. Hence for the equilibrium to be sustained, there must exist an upper bound of $\bar{t}(\pi)$ which is easily calculated by equating $\tau(b,b,\zeta_i^*) = \tau(a,b,\zeta_i^*)$.

Proof D (provided in Proposition 1 in Levy 2004):

By total differentiation of the indifference equation when $p = 1$, one has

$$\frac{\mathrm{d}t^*(.)}{\mathrm{d}\pi} = \frac{\frac{\mathrm{d}\frac{1-v}{v}}{\mathrm{d}\pi}}{\frac{\mathbf{d}k_\theta}{\mathrm{d}t^*} - \frac{\mathrm{d}\frac{1-v}{v}}{\mathrm{d}t^*}}$$

where $k_\theta = \frac{\tau(a,a,\zeta_i^*)-\tau(b,a,\zeta_i^*)}{\tau(b,b,\zeta_i^*)-\tau(a,b,\zeta_i^*)}$.

Since we have $\frac{\mathrm{d}\frac{1-v}{v}}{\mathrm{d}\pi} > 0$, $\frac{\mathbf{d}k_\theta}{\mathrm{d}t^*} > 0$, and $\frac{\mathrm{d}\frac{1-v}{v}}{\mathrm{d}t^*} < 0$, therefore $\frac{\mathrm{d}t^*(.)}{\mathrm{d}\pi} > 0$.

Chapter 4

Media persuasion and voter welfare

4.1 Motivation

Voting is a popular institutional apparatus to aggregate information and take better social decisions.[1] By making privately informed voters cast independent votes, society can increase the probability of electing policy alternatives that are welfare enhancing for the voters, particularly when voters have common preferences. In such circumstances, the role of an informed media or expert forecaster can be decisive. Behind the cry for the right to information and freedom of press lies an argument that media keeps voters well aware of key social and economic variables so that their personal judgments are more informed.[2]

It is often the case that the media has its own biases that reflect preferences of a minority of the population. A survey by Lichter et al. (1986) suggests that in the decade from 1975 to 1985, conservative ideologies outnumbered liberals among the American

[1]The contents of this chapter is joint work with Peter Postl and Jaideep Roy.

[2]Of course, media has other roles in public life that are also useful, such as keeping a check on corruption and crime. The model presented in this chapter abstracts away from these issues.

public while during that period close to three quarters of journalists held strong liberal views. With the power to communicate publicly, one would expect an informed (but biased) media to indulge in deliberate manipulation of social decisions through instruments such as keeping the news vague or revealing the truth only if certain circumstantial evidence is available. This can make media advice partly unreliable. To this end, Watts et al. (1999) provides evidence about voter perception of biased media news during the 1988, 1992 and 1996 presidential elections in the US. The study reveals that there was a rise in public perception that the media was liberally biased and a leading cause of this was an increased participation of liberal elites in news items. Yet, the most influential media sources in democratic societies are professional organizations or individuals who care about their reputation as a reliable platform for public debates and news in the future. Hence even known biases of the media cannot eliminate entirely the credibility of the news when it is transmitted.

While public knowledge about the media's reputation concerns makes the media better placed to credibly transmit any information in spite of its biases, this power of credibility in turn enhances its ability to manipulate voting outcomes. On the other hand if it is known that the media does not care about its reputation, it may not enjoy the same public trust as its reputation caring counterpart would. While the ability of media without reputational concerns to inform is then less, so also is its power to manipulate. It then remains ambiguous what is better for the voters: higher credibility (at a cost of higher ability to manipulate) or lower ability to manipulate (at a cost of lower credibility). Given this ambiguity, in the model studied in this chapter we ask what are the theoretical consequences of the presence of reputational concerns of the media on the welfare of the voters. In particular, we ask if the presence of reputation driven media transmitting credible news unambiguously improves ex-ante voter welfare. We show that the answer depends upon various aspects of the environment including size of the constituency, degree of conflict between the voters and the media and other informational parameters like priors and signal strengths of voters' private information. In general, media presence tends to hurt when the constituency is large and voters receive strong private signals.

We study a society represented by an odd number of voters. The voters face uncertainty over the true state of the world and must choose collectively (via the majoritarian voting rule) between two alternatives, X and Y. They have common preferences over states and alternatives and hold a common prior over the states. In addition, each voter receives private information about the state. The quality of this information is common and reflects the general degree of individual awareness in the society.[3]

The media due to reputation concerns can commit to credibly transmit information by declaring an interval partition of the state space such that the true state is always contained in the interval declared by the media. However, the media has preferences that are not perfectly aligned with those of the voters. In particular, the media prefers X in all states.[4] After the interval containing the true state is declared to the voters, voting takes place.

The benchmark model is normalized in a manner where without reputation, the media cannot credibly commit that the true state will always be contained in the interval it declares. In this scenario no information can be transmitted by the media (and all results we report below where the media is absent can also be interpreted as outcomes with a

[3]Individual awareness is typically reflected in the general level of education or other factors which influence the ability of a voter to analyze privately obtained information.

[4]Our results remain qualitatively intact in a more general environment where in some states the media can prefer Y.

media that does not care about future reputation). The resulting voting subgame resembles a common interest jury environment. Under the simple-majoritarian rule, there is a Bayes-Nash equilibrium (in weakly undominated strategies) where each voter votes on the basis of his private signal. It is well known that if the precision of signals is smaller than some cut-off value, pooling appears unambiguously in equilibrium where all voters commonly vote for one of the alternatives with probability 1 as their judgments are overwhelmed by their (common) priors. Hence, the ex-ante voter welfare remains invariant with the size of the constituency. When the signal strength is higher than this cut-off, the equilibrium becomes fully separating where an individual vote perfectly reveals the voter's private signal. In that case, as the size of the constituency increases, standard Condorcet Jury Theorem (CJT henceforth) arguments come into play. Consequently, the voters' ex-ante welfare increases monotonically with the size of the constituency.

When reputed media (henceforth, media) is present, we look at equilibria that maximize the media's ex-ante payoff. These equilibria are typically informative and can be thought of as ones where the media has the highest ideological influence over the social decision. Here, by revealing information carefully, the media can manipulate voting behavior to its own benefit. As in some states the two sides hold conflicting preferences, this may hurt the voters. Yet, at the time voters receive a piece of news, they find the news useful as privately they still remain only partially informed of the true state and know that the informative content of the news transmitted by the media can be relied upon.

In our analysis, we first consider the benchmark model with a single voter (or decision maker, DM in short) and then proceed to the multi voter case. If the media chooses to transmit informative news, then both in the case of a single DM or in the multi-voter case, it will typically send slanted news that either endorses its preferred policy X or recommends against it. We show that with a single DM, the presence of the media can never affect welfare adversely. This result is however altered when multiple voters are considered. We show that regardless of the size of the constituency, media presence can adversely affect the ex-ante probability of a correct decision and hence voters' welfare. If the prior bias of the voters is towards what the media wants (suggesting smaller conflict between the two sides), news will not be informative if voters private signals carry little information (i.e. an unaware society). As the voters individually get more aware of the uncertainties, informative news will be transmitted. Moreover, media presence will necessarily hurt voter welfare when the constituency is large. This perverse effect of informative news can appear in small constituencies as well and we provide some characterizations in this respect.

The outcomes change significantly when the prior bias of the voters is against what the media wants (suggesting larger conflict between the two sides). In this case for a sufficiently aware society, under certain scenarios the media transmits information such that any news slanted towards media's bias will be fully revealing, while news with a slant against media's own preference will be inconclusive. Interestingly, for these cases, the voters will follow the media slant only when the media endorses what it wants but vote according to their private signals when the news is slanted against the media's bias. We show that for a sufficiently aware society, the presence of the media can both be beneficial and harmful for welfare in these cases. However, for a society where the level of awareness is low, we show that the presence of the media is always welfare improving.

These results suggest that valuable news from a biased media is always welcome when the social decision is taken by a single DM in the sense that it can never reduce the ex-ante welfare of the DM. However, as democracy spreads and the number of voters get large, a reliable source of news can transmit immiserizing information in the sense that it can reduce ex-ante voter welfare. It is important to note that while the possibility of immiserizing information in our model is driven by the presence of strategic incentives of the media, similar public information can appear from non-strategic actors as well or even from sources whose intention is to send as much information as possible under the belief that more information cannot hurt the voter. This is specially true in the case of court trials where the judiciary tries to ensure that the trial is as informative as possible. Yet, since not all trials can reveal the truth with certainty, one may ask if and when any additional (but partial) public information adversely affects the probability of wrong judgments. Our results then indicate that when the trial is known to provide partially informative slants with evidential input, the probability that a jury takes the correct decision can go down, though such trials are always welcome if the jury is replaced by a dictatorial judge (single DM in our case). Moreover, when the jury is a priori biased towards one outcome (say acquittal) and the jury members receive strong private signals, using a jury may be better than a dictatorial judge. While a full analysis of these issues is beyond the scope of the model in this chapter, this is an important avenue for future research.

The social value of public information has been a well addressed subject since the work of Hirshleifer (1971). In a model with complementarities, Morris and Shin (2002) shows that public information can hurt social welfare while in the investment game of Angeletos and Pavan (2004) and in a monetary policy game of Hellwig (2005), public information necessarily improves welfare. Also, Angeletos and Pavan (2007) show how welfare properties of public information depends not only on the form of strategic interaction but also on other external effects that determine the gap between equilibrium and efficient use of public information.[5] However, in all these works, transmission of public information is non-strategic.

Our work is also related to two other strands of literature, namely, cheap talk and voting, and to an emerging area of research that links the two. The seminal work by Crawford and Sobel (1982) describes a framework of communication between an informed sender and an uninformed receiver (or decision maker) where messages are costless and do not directly affect the utility of the sender. However, we consider a particular setting where the reputation-driven sender (the media) can potentially transmit vague information but cannot lie. This is similar to the 'verifiable disclosure' approach to communication, initiated by Grossman (1981) where the sender cannot lie but can withhold information. Our approach to modeling a reputation-driven sender has resemblance to Chen (2011), who considers a finite message space and defines an 'honest' sender to be one who by nature always reports the message that is closest to her observation.

Our model fundamentally differs from the above body of work in two aspects: First, we model a binary decision problem where the action space of the voters is finite and not continuous (as in the standard Crawford-Sobel framework). Second, we consider a single sender and multiple receivers with *partially* aligned interests, in the sense that there is a range of states of the world where the preferred choice of the receivers (voters) as well as the sender (media) is identical, whereas for some states they vary. In contrast in the above papers, there is conflict of interest in each state of the world.

Next, consider our results concerning certain scenarios where the information provided

[5] See also Bikchandani et al. (1992), Cao and Hirshleifer (2000) and Gersbach (2000) among others for related works on impact of public information on social welfare.

by the sender is such that the voters vote according to their private signals. In these instances the welfare analysis of the voters is related to the probability of correct decisions in the CJT literature. Austen-Smith and Banks (1996) study the innocuousness of the assumption made in the statement of CJT that the voters vote 'sincerely' (that is, even when they are in a group they vote as if alone) and introduces strategic voting. They show that 'sincere' voting, which implies voting in accordance to private signals is equivalent to strategic voting if the aggregation rule is simple majoritarian. For relatively high levels of precision of private signals received by the voters, this result is obtained in the communication game we study as well.[6]

Our work is also very closely related to a relatively scant but growing literature on how social elites (media, popular political and apolitical figures) can influence mass opinions through public information (for some review articles on this, see Mutz et al. (1996), Kinder (1998) and Druckman and Lupia (2000)). Iyenger and Kinder (1987) and Lupia and McCubbins (1998) study the role of media in persuading politically aware citizens to elect parties in democratic societies. Zaller (1992) suggests related theories of how political awareness and greater cognitive engagement of citizens with public sources of political news can affect political opinions and support. Mullainathan and Shleifer (2005) address the idea that the media may represent biased elitist opinions regarding political choice and that voters 'like' the influence cast by such political endorsements of the media. That political commentators can be reputation driven (because of career concerns) has been noted in Gentzkow and Shapiro (2006) though they derive biased media coverage without ideological considerations. Other works on political economy and the role of the public endorsements (see for example Grossman and Helpman (1999) and Stromberg

[6]See also Feddersen and Pesendorfer (1996, 1998) for more on this issue.

(2004)) study how direct or indirect mass communication with the voters can influence electoral outcomes.

Besley and Prat (2006) and Anderson and McLaren (2010) study how biased media can communicate with voters using ex-post verifiable messages about quality of competing parties. In particular, Besley and Prat (2005) study a scenario where there are multiple media outlets, where each media outlet has two possible sources of making profit: the first component consists of commercial profits, while the second corresponds to profits garnered from collusion with the government. The first component is audience-driven, which increases if the media outlet reports interesting information. The paper shows that when the media outlets are homogeneous, the number of independent media outlets and the probability that the government controls news provision in equilibrium are inversely related. The intuition behind the result is that every time the government pays an outlet to suppress its information, the commercial revenue of the other outlets goes up since the degree of competition they face commercially goes down. If the government intends to buy out all the media organisations, it has to pay each of them as if it were a monopoly provider of unbiased information. Anderson and Mclaren (2010) consider the case when the consumers of news media do not know how much information is possessed by the media. Hence if there is a lack of news, citizens do not know whether that is due to lack of information or because information is being strategically withheld. Uncertainty about how much information the sender has prevents complete inference regarding the sender's information, with the result that who owns the news organization (differentiated by preference heterogeneity) can make a difference to what the public learns in equilibrium. In contrast Chakraborty and Ghosh (2012) studies a cheap talk model where elite and partisan media can advertise about the quality of two competing candidates in an otherwise Hotelling-Downs framework (with sincere voting). In their paper, the ideological positions of different media outlets make candidates strategically position themselves on the ideology line in order to gain media attention. Voters are sophisticated enough to discount both the media endorsements and the pandering of parties towards the media outlets. Among other characterizations of resulting electoral equilibria they demonstrate the possibility of situations where the voters are better off when there are no media outlets present even though their existence generate useful information transmission. The idea there is that while media reveal information about quality of competing parties, their existence in turn affects equilibrium policies in a way that ultimately can hurt social welfare. Our welfare analysis shows that this phenomenon of immiserizing information can be obtained through a different channel involving reputation of the sender who sends public messages through news transmissions even when policies are exogenously given. Also, Chakraborty et al. (2012) report another instance of immiserizing public information where media can affect equilibrium policies in a Hotelling-Downs model with two politicians and an unknown location of the median voter. They show that the media can first affect policy making and then affect electoral outcomes, thereby leading to policy convergence, though the Median Voter Theorem may not hold universally.

4.2 The Model

An odd number of voters with common preferences have to vote over two alternatives. The timing of the game we study is as follows: there is a media, which announces that news will be transmitted in accordance to a signalling technology (made up of partitions of the state space). Then the state is realised and a partition which is in accordance to the signalling technology announced earlier by the media is declared to the voters. Due to reputation concerns, it is common knowledge that the declared partition will necessarily contain the true state, and the media cannot declare an interval that does not contain the true state. After the partition is declared, each of the voters receive informative signals regarding the state, and then voting takes place. Once all votes cast by the voters are aggregated into a social decision, the media and the voters obtain their pay-offs depending on the social decision and the true state.

We model this environment in the following way.

$I = \{1, \cdots, n\}$ is the set of voters ($n \geq 1$ and odd), $A = \{X, Y\}$ is the set of alternatives and $\Omega = [0, 1]$ is the set of states.

Priors: The state $\omega \in \Omega$ is a random variable and agents have a common prior given by density $f(\omega)$ where f is non-atomic, and the distribution function is given by $F(\omega)$. Voters do not observe the true state ω.

Voters' preference: Voters have a common preference over A represented by the state-dependent strict preference relation $\succ$ such that for some $0 < \omega_v < 1$, we have $X \succ Y$ if $\omega \leq \omega_v$ and $Y \succ X$ if $\omega > \omega_v$. These preferences of the voters are represented by the utility function $u : A \times \Omega \to \mathbf{R}$ such that for $\zeta, \tau \in \mathbf{R}, \zeta < \tau$ we have:

$$u(X, \omega) = \begin{cases} \tau & \text{if } \omega \leq \omega_v \\ \zeta & \text{otherwise} \end{cases}$$

and

$$u(Y, \omega) = \begin{cases} \tau & \text{if } \omega > \omega_v \\ \zeta & \text{otherwise} \end{cases}$$

Voters' private signals: Each voter $i \in I$ receives a private signal $s_i \in \{X, Y\} \equiv S$ whose precision is $p \in (1/2, 1)$, that is, $\mathbf{P}[s_i = X|\omega \leq \omega_v] = \mathbf{P}[s_i = Y|\omega > \omega_v] = p$.

Media's preference: The media strictly prefers X over Y in all states. This preference of the media is represented by the utility function $u_m : A \times \Omega \to \mathbf{R}$ such that for ζ_m, $\tau_m \in \mathbf{R}$ with $\zeta_m < \tau_m$ we have $u_m(X, \omega) = \tau_m$ and $u_m(Y, \omega) = \zeta_m$ for all $\omega \in \Omega$.

Size of ex-ante conflict: The case $F(\omega_v) > 1/2$ will be referred to as a case of *small conflict* between the voters and the media while *large conflict* will correspond to $F(\omega_v) < 1/2$.

Messages: The media sends a *public message* (that is observed by all voters). We model messages as follows: For $k \geq 1$, let $\Omega^k = \{\Omega_1, \cdots, \Omega_k\}$ be a k-element partition of Ω. Let the message set be $M^k = \{m_1, \cdots, m_k\}$. A *message strategy* of arity k is a function $m_k : \Omega \to M^k$ that maps each $\omega \mapsto m_k(\omega) \in M^k$ with the following literal meaning: $m_k(\omega) = m_j$ means $\omega \in \Omega_j$ for all $j = 1, \cdots, k$. Generic messages will be denoted as $m', m'' \in M^k$. Let $\mathcal{M}$ be the space of message strategies of all arities $k \geq 1$. The signalling technology that the media announces is characterised by the message strategy.

Voting and social decisions: A *voting strategy* for voter $i \in I$ is a function $v_i : M^k \times S \to A$ that maps the received message $m' \in M^k$ and the private signal s_i to generate a *vote* $v_i \in A$. We denote by $v = (v_1, \cdots, v_n) \in A^n$ a *vote profile* and use the shorthand $v(m', s)$ to denote $(v_1(m', s_1), ..., v_n(m', s_n))$.

The *social decision function* $\delta : A^n \to A$ is *majoritarian* and maps a vote profile $v \in A^n$ to an outcome $\delta(v) \in A$ such that $\delta(v) = X$ if and only if $\#\{i \in I | v_i = X\} \geq \frac{n+1}{2}$.

Lies and punishments: Once all the above decisions are taken, the voters observe the true state ω. At this stage, the voters pass a judgment about the 'trustworthiness' of the media. Fix any pair (Ω^k, M^k). Suppose the media uses some arbitrary message strategy $m_k : \Omega \to M^k$. We call a message $m_j \in M^k$, $j = 1, \cdots, k$ a *lie* if $\omega \notin \Omega_j$. In other words, a message that violates (ex-post) the 'literal meaning' clause defined above is a lie. The voters dislike lies and punish the media. Let c be the associated cost borne by the respective media in the event it is punished for lying. We shall assume $c > \tau_m$.[7]

Equilibrium: We focus on symmetric perfect Bayesian equilibria in pure strategies where voters use weakly undominated strategies.[8] As well established in the existing literature on strategic voting, a voting equilibrium thus generated is called *'informative'*, and we focus on this equilibrium in what follows. Under this class of equilibria, there is a distinction that is useful for our purposes: one where each vote reveals fully the voter's private signal (separating equilibrium) and the other where votes reveal no such information (pooling equilibrium). Also, we look at message strategies in equilibria which maximize the media's ex-ante payoffs, which we call the most influential and report the coarsest[9] among them. By the term *equilibrium*, in the rest of the analysis we shall mean a *coarse, influential and informative* equilibrium where voters vote informatively and the media is as influential as permitted by equilibrium conditions. For a formal definition of equilibrium, see Appendix 4.6.1.

[7] This is similar to Chen (2011). Also see Mertens and Zamir (1985) on conceptualizing misinformation.

[8] In our model this means that each voter follows a voting strategy in which he votes in favor of the alternative that is better for him after having made full use of his available information (which consists of the public message, the private signal received and if possible inference about the signals of the other voters from the pivotal vote profile).

[9] This means that among the set of all 'most-influential news coverage', the media uses that which requires minimal partitioning of the state space.

4.3 Single Decision Maker

We first study the model in a standard sender-receiver setting where there is a single receiver. Moreover, as we shall see in Section 4.4, much of the analysis we do now will be used directly when we study voting. So, suppose in the model described above, there is a single receiver or decision maker (DM), that is $n = 1$ (we denote this single 'voter' by i and use the notation '$\emptyset$' to denote the absence of the media and hence an empty message). We begin with the benchmark case where the media is absent.

Lemma 3 (Without Media)**.** *Suppose there is a single decision maker, that is $n = 1$. His optimal decision v_i has the following features:*

(a) Suppose $F(w_v) > 1/2$. Then,

(i) $v_i(\emptyset, s_i) = s_i$ if $p > F(\omega_v)$ and

(ii) $v_i(\emptyset, s_i) = X$ for each $s_i \in S$ if $p < F(\omega_v)$;

(b) Suppose $F(w_v) < 1/2$. Then,

(i) $v_i(\emptyset, s_i) = s_i$ if $p > 1 - F(\omega_v)$ and

(ii) $v_i(\emptyset, s_i) = Y$ for each $s_i \in S$ if $p < 1 - F(\omega_v)$.

If the strength of the private signal is sufficiently weak, then the degree of inference that can be drawn from it is low. In this case when the prior distribution is biased in favor of the alternative X (that is, $F(\omega_v) > 1/2$), the DM chooses X irrespective of his private signal. However, if the strength of his private signal is high, then the reliability of the signal prompts the DM to choose according to his private signal. When $F(\omega_v) < 1/2$, the probability of states where he prefers Y is higher than the states where he prefers X.

By analogous reasoning, he therefore chooses Y irrespective of his private signal in case his signal strength is sufficiently low, and chooses according to his signal otherwise.

We next move to the case when the media is present. As it is common knowledge that the media associates a high cost with the subsequent penalization owing to delivery of incorrect information, it can credibly pass any information and this enhances its ability to influence social decisions. The following two lemmas deal with the equilibrium actions in this case. In this framework, news is an interval of the state space. We call a news item *conclusive* in favour of a particular alternative if and only if in each feasible state included in the news item, the optimal social decision of the voters is in favour of that particular alternative. Any news that violates this property will be called inconclusive. Also, a news item is called X-endorsing (Y-endorsing) if the resulting probability mass over the declared interval (before private signals are incorporated) is higher for X (Y) than for Y (X).

Two classes of message strategies are considered both for the single DM or multiple voters cases: Under *Class 1* message strategies, the state space is partitioned into two intervals, such that the left interval Ω_1 is inconclusive, while the right interval Ω_2 provides conclusive evidence towards Y. If the state belongs to Ω_1, then upon receiving the resultant message the endorsement of the news in favour of X is strong enough to ensure that the voter chooses X irrespective of his private signal. However, the alternative Y is always chosen if the state belongs to Ω_2, which is the less preferred alternative of the media. Under *Class 2* message strategies, a potentially tri-partitional message strategy is considered such that: if the state is declared to belong to the left partition Ω_1, the voter follows a pooling strategy of voting X irrespective of the private signal received. If the state is declared to belong to the middle partition Ω_2, the voter follows a separating strategy of voting according to the private signal received. If the state is declared to belong to the right partition Ω_3, the voter follows a pooling strategy of voting Y. The optimal message strategies under *Class 1* and *Class 2* are characterised, and then the two are compared to find the better message strategy that maximises the ex-ante welfare of the media. From the optimisation problem it follows that the optimum message strategy under *Class 2* always reduces to a two-partitioned message strategy both for the single voter or multiple voters cases. The optimum *Class 2* message strategy is such that the voters follow a separating voting strategy when one interval is declared, and follow a pooling strategy when the other interval is declared. A further comment may be made in this connection. Consider the following class of message strategies, say *Class 3*, which is described as follows: the state space is partitioned into two intervals, such that the left interval Ω_1 provides conclusive evidence towards X, while the right interval Ω_2 is inconclusive . If the state belongs to Ω_1, then upon receiving the resultant message the voter chooses X irrespective of his private signal. However, the alternative Y is always chosen if the state belongs to Ω_2, which is the less preferred alternative of the media. It is easy to check that *Class 3* message strategies will always correspond to a lower level of ex-ante pay-off for the media than any *Class 1* message strategy, and hence confining our attention to *Class 1*and *Class 2* message strategies is without loss of generality.

Lemma 4 (Small Conflict: $F(\omega_v) > 1/2$)**.** *Suppose there is a single decision maker with small conflict with the media. Then, there exists a unique $\omega^* > \omega_v$ such that the media announces whether or not $\omega \leq \omega^*$, that is, $\Omega_1 = [0, \omega^*]$ and $\Omega_2 = (\omega^*, 1]$. Moreover,*

(a) if $p < F(\omega_v)$, then $\omega^* = 1$ and $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$, i.e., news contains no information, and

(b) if $p > F(\omega_v)$, then $F(\omega^*) = F(\omega_v)/p$ (that is, $\omega^* > \omega_v$), $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsing news is inconclusive while Y-endorsing news is fully revealing, and the decision maker always chooses in accordance with the media endorsements.

With small conflict, the prior distribution is biased in favor of the (media's favorite) alternative X. From Lemma 3, it follows that when no information is provided, the DM chooses X irrespective of his private signal if the strength of his private signal is sufficiently low. Since the media prefers the alternative X for all states of the world, this is the ideal scenario for it and therefore it chooses not to transmit any information in equilibrium. However, if the signal strength of the DM is high, under no additional information, he chooses according to his private signal, which prompts the media to intervene in this scenario. In this case, the media optimally chooses to follow *Class 1* message strategy, such that in the most influential equilibrium, the length of the X-endorsing interval is maximized. To see this, observe that in order to make the DM adopt a pooling strategy of voting X, the message should provide credible information that is sufficiently strong in favor of X (which means the mass of states greater than ω_v that may have generated the same message needs to be sufficiently small) so that the DM chooses X even when he receives a private signal of Y. To achieve this end, a single message should be delivered for all states in $[0, \omega_v]$ (which ensures maximal evidence in favor of states for which the voter favors X) along with other states in $(\omega_v, 1]$. After having included the entire support $[0, \omega_v]$, the maximum point ω^* up to which the news can be thought to be generated from a left interval sustaining a resultant pooling strategy of voting X satisfies the condition $F(\omega^*) = F(\omega_v)/p$ which implies that $\omega^* > \omega_v$.

Remark 2. *Note that ω^* is a decreasing function of p. This implies that the degree of* *inconclusiveness of news endorsing X goes down as the signal strength rises, that is, a more informed DM receives more information.*

We next move to the case where the conflict between the media and the DM is large.

Lemma 5 (Large Conflict: $F(\omega_v) < 1/2$)**.** *Suppose there is a single decision maker with large conflict with the media. Then there exists a unique $\omega^* \in (0,1)$ where the media announces whether or not $\omega \leq \omega^*$, that is, $\Omega_1 = [0, \omega^*]$ and $\Omega_2 = (\omega^*, 1]$. Moreover,*

(a) If $p > 1 - F(\omega_v)$, then

(i) if $F(\omega_v) < 1 - 1/\sqrt{2}$, then ω^* satisfies $F(\omega^*) = (F(\omega_v)/p) - ((1-p)/p)$, i.e. $\omega^* < \omega_v$, with $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = s_i$, i.e., X-endorsement is fully revealing, Y-endorsement is inconclusive, the DM follows only an X-endorsement but votes according to private signal with a Y-endorsement;

(ii) if $F(\omega_v) > 1 - 1/\sqrt{2}$, then if $p < 1/(2(1 - F(\omega_v)))$, we have $F(\omega^*) = F(\omega_v)/p$ i.e. $\omega^* > \omega_v$, with $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsements are inconclusive while Y-endorsements are fully revealing and the DM follows media endorsements; However if $p > 1/(2(1 - F(\omega_v)))$, then the message strategy and voting behavior is similar to part (a.i).

(b) If $p < 1 - F(\omega_v)$, then

(i) when $p < 1/\sqrt{2}$ we have $F(\omega^*) = F(\omega_v)/p$, i.e. $\omega^* > \omega_v$, with $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsements are inconclusive while Y-endorsements are fully revealing and the DM follows media endorsements, and

(ii) when $p > 1/\sqrt{2}$ we have $F(\omega^*) = F(\omega_v)/(1 - p)$, i.e. $\omega^* > \omega_v$, with $v_i(\Omega_1, s_i) = s_i$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsements are inconclusive

while Y-endorsements are fully revealing; however, the DM follows only the Y-endorsements, but votes according to private signal with an X-endorsement.

When $F(\omega_v) < 1/2$, the prior distribution is biased in favor of the alternative Y that the media wants to defeat. Consider a highly aware society. If the degree of conflict is very large, the media chooses to follow a bi-partitioned message strategy which induces the DM to follow the media slant if the news is in favor of X, while he votes according to his private signal if the news is in favor of Y. The media finds this voting behavior ex-ante profitable, for it is assured of its most favored alternative X when $\omega \in [0, \omega^*)$, while there still is a positive probability that X will be voted for when $\omega \in [\omega^*, 1]$. The same message strategy and induced voting behavior is maintained when the degree of conflict is lessened, along with the characteristic that the level of awareness exceeds a threshold value. However, if the awareness level is lower than the threshold limit, the media in a most influential equilibrium follows a two-interval message strategy such that the DM follows a pooling strategy of choosing X when the state belongs to the left interval endorsing X, and Y when it belongs to the right interval endorsing Y.

Now consider a sufficiently unaware society where in the media's absence the DM chooses alternative Y in each state irrespective of his private signal, which is the worst possible outcome for the media. Note that in this case even when the entire length of $[0, \omega_v]$ is included in a single message, the DM cannot be induced to vote for X for the entire region $(\omega_v, 1]$ when he receives a private signal of X, because he does not have enough faith in the precision of his signal. In this case, under the most influential equilibrium the media follows a message strategy that satisfies the following characteristics: if the signal strength is greater than a cut-off value, the bi-partitioned message space is such that when the state belongs to the X-endorsing interval, the DM chooses according to his private signal. If the state belongs to the Y-endorsing interval, the DM chooses alternative Y irrespective of the private signal received. Here the length of the left interval is maximized by including the entire zone of $[0, \omega_v]$ and stretching the support of the interval to the maximal point such that the DM votes according to his private signal for all states in this interval. If the signal strength is less than the cut-off value, then the most influential equilibrium entails a bi-partitioned message space such that the DM chooses X irrespective of his private signal when the state belongs to the X-endorsing interval, and Y when it belongs to the Y-endorsing interval.

4.3.1 Welfare Analysis with a Single Decision Maker

While we have shown that the media can and will influence the decision, it turns out that a single DM weakly benefits from media presence. In this regard, we have the following proposition.

Proposition 3 (Media is weakly welfare-improving). *In a scenario with a single decision maker, the presence of a media can only enhance ex-ante welfare. In particular,*

(a) Suppose $F(\omega_v) > 1/2$. Then,

- *(i) When $p < F(\omega_v)$, the decision maker's welfare is invariant to the presence of the media.*
- *(ii) When $p > F(\omega_v)$, the decision maker's welfare is higher under the presence of a media;*

(b) Suppose $F(\omega_v) < 1/2$. Then,

- *(i) When $p > 1 - F(\omega_v)$, the decision maker's welfare is higher under the presence of a media;*

(ii) When $p < 1 - F(\omega_v)$, then

- *If $p < 1/\sqrt{2}$, the presence of a media is always better for ex-ante voter welfare, whereas*
- *If $p > 1/\sqrt{2}$, the ex-ante voter welfare is invariant to the presence or absence of the media.*

Consider the case of low conflict where solely based on the prior distribution, the inclination of the DM is towards alternative X which the media prefers (that is, when $F(\omega_v) > 1/2$). In this case if the inclination based on prior information exceeds the strength of the private signal of the DM, then no additional information appears in equilibrium as the media's best alternative always wins with probability 1. Hence in this case the ex-ante welfare of the DM remains same both in the presence or absence of the media. Moreover, in the case where the media finds it optimal to transmit some information through its news, the DM is never worse-off with the news. For example, consider (a.ii) of the proposition. Here by Lemma (4) part (b) it follows that in equilibrium the media makes the DM choose X irrespective of his signal for all states $[0, \omega^*]$, where $\omega_v < \omega^*$. This implies that information provided by the media may over-ride the informative private signal of the DM when $\omega \in (\omega_v, \omega^*]$, prompting him to choose the less desirable alternative for these states. On the other hand, with the media the DM is assured that he will choose his most favored alternative when $\omega \in [0, \omega_v]$. The net effect is that the ex-ante welfare of the DM is higher with news coverage and hence the presence of a media augments his welfare.

Now consider the case of large conflict, represented by $F(\omega_v) < 1/2$. In this case the power of the media to manipulate the DM is limited due to large conflict of preferences, and hence the information provided by the media can never hurt the ex-ante welfare of the DM.

In other words, we can think of the result in the following manner. There are two sources of information for the single DM: his private signal and the endorsing news provided by the media. Under certain scenarios, news provided can over-ride the private signal of the DM and make him worse-off for some states of the world. However, reliable news also enables him to choose his desired alternative with a higher probability for other states. Since for a single DM, only one informative signal is used to generate final decisions, it can never be that the welfare of the DM is reduced by introducing an additional source of information available from the media, since the potential gains for some states outweigh the potential losses for other states owing to the introduction of this additional information source. In other scenarios, the news provided complements the action of the DM in the following manner: for some states of the world, it induces the DM to vote according to his private signal (which he would would have done anyway even in the absence of the news), while for other states the informational content of the news leads the DM to choose his most preferred alternative without fail. Hence the DM always welcomes the presence of the media. Seidmann (1990) considers information transmission in a single receiver setting with no costly talk where the type of the receiver is private information. In this case, any message provided by the sender induces a distribution of the receiver's actions across its types, and there may be two messages that induce distributions over actions that are not ordered by stochastic dominance. Different types of senders who agree in their preference rankings of non-stochastic actions may differ in their preference rankings of these non-ordered distributions, thereby making effective communication possible. However, in our model we focus on costly talk where the preference ranking of every possible type of sender over the distribution of the receiver's action is identical.

4.4 Information Transmission and Voting

We have seen that media presence is always welfare improving with a single DM. With multiple decision makers who take decisions via voting, news otherwise useful can coordinate beliefs of voters in such a way that aggregate decisions are less efficient. When the media sends public messages and voters vote strategically, we ask what sort of information is credibly transmitted and when can the media manipulate social decisions in its favor. The results we obtain without a media or a media with small conflict are similar to Lemmas 3 and 4 though the proofs are more involved and provided in the Appendix.

We begin with the following lemma for the game without media.

Lemma 6 (Voting without Media)**.** *Suppose there are $n \geq 3$ independent voters but there is no media presence. The equilibrium voting strategy for each voter $i = 1, ..., n$ is the same as those of a single decision maker described in Lemma 3.*

Lemma 6 is readily understood from the observation that under the simple majoritarian rule, in a separating voting equilibrium where each vote reveals the voter's private signal, the pivotal vote profile provides perfectly balanced evidence in favor of either alternatives, and hence the decisive piece of private evidence to be considered by the voter is just his own signal as is the case with a single DM. This then leads to the result that the equilibrium behavior of each voter in a multiple voter case (under our equilibrium criterion of informative voting) is the same as the scenario where a single decision maker is present.

Given Lemma 6, we now allow media presence. We first deal with the case when the conflict of preference between the voters and the media is small.

Lemma 7 (Voting with Small Conflict: $F(\omega_v) > 1/2$)**.** *Suppose in the presence of an informed media there are $n \geq 3$ voters and suppose the conflict between the voters and the media is small. Then the equilibrium actions of the media and the voters are same as those with a single decision maker in the presence of the media as described in Lemma 4.*

If the inclination of the voter based solely on the prior distribution to vote for X exceeds the strength of his private signal, then no additional information is made available to him even when a media is present, and each voter votes X irrespective of their private signals. In this case the unanimous decision is X for all states of the world which the media prefers. This rationalizes her choice of not transmitting any information to the voters. When the signal strength is high, the intuition behind the particular message strategy followed by the media is identical to the logic provided in explaining Lemma 4.

Apart from news that reveals no information in any state (which appears when the voters' posteriors sans media news always tilt towards what the media wants), the media's problem (both in the single DM or multiple voter case) reduces to a choice between two types of informative news coverage: (i) only the X-endorsing news is inconclusive and (ii) potentially tri-partitional message strategy where it is possible to have coverage where slants in favor of both X and Y-endorsing news is conclusive. When $F(\omega_v) > 1/2$, we prove that type (i) dominates unambiguously both in the single DM or multiple voter case. However, when $F(\omega_v) < 1/2$, the problem gets more nuanced as already reflected in Lemma 5 even with a single DM.

In general, the choice between these two types of news depends crucially on what we call Condition (∗). Let

$$J(n,p) = \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} p^j (1-p)^{n-j}.$$

Condition (∗):

$$J(n,p) \geq \frac{p(2-F(\omega_v))-1}{(2p-1)(1-F(\omega_v))}$$

Note that the expression $J(n,p)$ is the probability that a constituency of size n and awareness p makes a correct social decision when voters vote in accordance with their private signals. Then, (∗) provides a lower bound on this probability. This lower bound increases in p and decreases in ω_v.

While (∗) holds unambiguously when $F(\omega_v) > 1/2$, it is neither universal nor empty when $F(\omega_v) < 1/2$. The following lemma specifies equilibrium actions under $F(\omega_v) < 1/2$ by using (∗) directly. It shows that only when p is large, condition (∗) matters; when it holds, type (i) messaging dominates while when it is violated type (ii) messaging dominates. We then discuss and provide examples concerning the condition. The lemma uses a particular value of p which we call p' where

$$p' = \frac{(27-3\sqrt{78})^{\frac{1}{3}}}{6} + \frac{(3\sqrt{78}+27)^{\frac{1}{3}}}{6} \approx .76.$$

Lemma 8 (Voting with Large Conflict: $F(\omega_v) < 1/2$)**.** *Suppose in the presence of an informed media there are $n \geq 3$ voters and suppose the conflict between the voters and the media is large. Then, there exists a unique $\omega^* \in (0,1)$ such that the media announces whether or not $\omega \leq \omega^*$, that is, $\Omega_1 = [0,\omega^*]$ and $\Omega_2 = (\omega^*,1]$. Moreover,*

(a) If $p > 1 - F(\omega_v)$, then

(i) If (∗) holds then ω^* satisfies $F(\omega^*) = F(\omega_v)/p$, i.e. $\omega^* > \omega_v$, with $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsement is inconclusive, Y-endorsement is fully revealing and voters follow media endorsements;

(ii) If $(*)$ does not hold then ω^* satisfies $F(\omega^*) = (F(\omega_v)/p) - ((1-p)/p)$, i.e. $\omega^* < \omega_v$, with $v_i(\Omega_1, s_i) = X$ for each $s_i \in S$ and $v_i(\Omega_2, s_i) = s_i$, i.e., X-endorsement is fully revealing, Y-endorsement is inconclusive, voters follow only an X-endorsement but vote according to their private signals with a Y-endorsement;

(b) If $p < 1 - F(\omega_v)$, then

(i) for $n \geq 5$, the message strategy and voting behavior is same as in (a.i).

(ii) for $n = 3$, for all $p < p'$, the message strategy and voting behavior is same as (a.i). When $p > p'$, then $F(\omega^*) = F(\omega_v)/(1-p)$, i.e. $\omega^* > \omega_v$, with $v_i(\Omega_1, s_i) = s_i$ and $v_i(\Omega_2, s_i) = Y$ for each $s_i \in S$, i.e., X-endorsements are inconclusive while Y-endorsements are fully revealing; however, voters follow only the Y-endorsements but vote according to private signals with an X-endorsement.

From the lemma it follows that the media always transmits news that is slanted either in favor of X or Y. We first discuss the case when the society is sufficiently aware and each voter votes according to his private signal in the absence of the media. Here, if the media is present the kind of news it will choose to transmit depends on whether $(*)$ holds or not.

We now provide some sufficiency conditions for $(*)$ to hold. Let

$$Q(n, p; \omega_v) = J(n, p)(F(\omega_v) - 1)(2p - 1) + p(2 - F(\omega_v)),$$

and note that $(*)$ holds if and only if $Q(n, p; \omega_v) - 1 \leq 0$.

Highly aware society: If $p = 1$, then $J(n, p) = 1$. Hence in this case, $Q(n, 1; \omega_v) - 1 = 0$. Also note that $\frac{\partial(Q(n,1;\omega_v)-1)}{\partial p}|_{p=1} = F(\omega_v) > 0$. This shows that when $p \to 1$, the expression $(Q(n, 1; \omega_v) - 1) < 0$. Hence $(*)$ is always satisfied for all n if the precision of the signal received individually by the voters is high enough.

Large constituency: Also consider the case when the size of the electorate is very large. Note that $J(n, p) \to 1$ as $n \to \infty$, and hence corresponding to this case $Q(n, p; \omega_v) - 1 = p(F(\omega_v) - 1) < 0$ for all $p \in (1/2, 1)$. This shows that condition $(*)$ is always satisfied if the number of voters is sufficiently large.

Intermediate awareness, not-too-large conflict, small constituency: Moreover, note that $Q(n, 1; \omega_v) - 1 \leq 0$ if $J(n, p) \geq (p(2 - F(\omega_v)) - 1)/((2p - 1)(1 - F(\omega_v)))$, which is always satisfied if the RHS of the inequality is less than or equal to $1/2$. This yields $p \leq \frac{1+F(\omega_v)}{2}$. Since $(*)$ is valid for the case $p > 1 - F(\omega_v)$, we must therefore ensure $1 - F(\omega_v) < \frac{1+F(\omega_v)}{2}$, which yields $\frac{1}{3} < F(\omega_v)$. Hence we know that if $\frac{1}{3} < F(\omega_v) < \frac{1}{2}$ and $1 - F(\omega_v) < p \leq (1 + F(\omega_v))/2$, condition $(*)$ always holds. As a specific example, consider $F(\omega_v) = .35$. In this case $1 - F(\omega_v) = .65$, and $\frac{(1+F(\omega_v))}{2} = .675$. Consider $p = .66$, $n = 3$. In this case $Q(n, p; \omega_v) - 1 \approx -.063 < 0$, and hence $(*)$ is satisfied.

When $(*)$ does not hold: The complement of $(*)$ is non-empty as well. We construct an example. Let $n = 3$ and $F(\omega_v) = .18$. In this case for intermediate values of the precision of the private signal (that is when $0.63 < p < 0.9$), $(*)$ is violated while for the cases $1/2 < p < 0.63$ or $0.9 < p < 1$, $(*)$ is satisfied. As a specific example, consider $n = 3$ and $p = .7$. For these values, $Q(n, p; \omega_v) - 1 \approx .017 > 0$, and hence $(*)$ is violated in this case.

Given the above discussion, suppose $(*)$ is satisfied. Lemma 8 shows that in this case the media transmits news that is slanted either in favor of X (in which case the content of the news is inconclusive) or Y (here the content of the news is fully revealing). In both cases the voters vote in favor of the alternative towards which the news provided is slanted. If, however $(*)$ is violated, the media transmits news that is either slanted conclusively in favor of its own preferred alternative X or inconclusively in favor of its less preferred alternative Y. Upon receiving news that is decisively slanted towards X, the voters always vote X. However, if they receive news from the media that is inconclusively slanted towards Y, they vote in accordance to their private signals. This may appear counter intuitive since here the voters support what the media likes when it asks them to do so, but they are careful and use their private information when the media endorses what it does not like. However, it is worth noting that the voters would have voted according to their private signals had the media been absent. Hence, when the media is present, it regulates the information content of the news to make the voters choose for sure the preferred alternative of the media (X) for as many states as possible, while for others they are left to behave as they would have in the media's absence. This leaves the media with a positive probability of having the social decision to be X when $\omega \in [\omega^*, 1]$.

Now consider a society with low awareness levels wherein in the media's absence the voters would have been influenced by the prior and unequivocally voted for Y irrespective of their private signal received. Note that in this case it is impossible for the media to make the voters vote X for all $\omega \in (\omega_v, 1]$ when their private signals is X even when the entire stretch $[0, \omega_v]$ is included in a single message. Hence the voting behavior of part (a.ii) is impossible to replicate here. In this scenario, the media optimally chooses between message strategy in part (a.i) of the lemma versus providing news of the following kind: either the news has an inconclusive slant towards X that induces the voters to follow their signals, or the voters are induced to vote in favour of the slant towards X. It is shown that for a sufficiently large electorate (greater than or equal to five), the latter type dominates the former. This is because under the latter, the media is surely able to implement X when $\omega \in (\omega_v, \omega^*]$, whereas under the former type of message strategy Y will be chosen for these states under a large electorate, since each voter votes according to his private signal.

4.4.1 Welfare

We now compare ex-ante voter welfare across absence and presence of media. When the prior distribution is biased in favor of X (that is, for the case of small conflict), we have the following result. With low signal precision, the ex-ante welfare of the voter under both cases is the same. Otherwise, the ex-ante welfare of the voter is different for the two cases. Here we may differentiate among the following scenarios: for a sufficiently large size of the electorate (greater than or equal to seven), the ex-ante welfare of the voter is always higher in the absence of the media. We however show that this is not a general feature of the model. If the number of voters is low (either three or five), then for an intermediate range of signal precision, ex-ante welfare of the voter is higher when the media is present, while for extreme values (either high or low) of signal precision ex-ante voter welfare is higher in the absence of the media. These observations are made precise in Proposition 4.

Proposition 4 (Welfare under Small Conflict: $F(\omega_v) > 1/2$)**.** *In a scenario with* $n \geq 3$ *voters, the presence of a media with small conflict may or may not enhance ex-ante welfare. In particular,*

(a) When $p < F(\omega_v)$*, the ex-ante voter welfare is invariant to the presence of the media.*

(b) When $F(\omega_v) < p$*,*

(i) If $n \geq 7$*, the ex-ante voter welfare is higher in the absence of the media;*

(ii) If $n < 7$*, there exists* $1/2 < k^*(n) < p$ *such that (1) when* $k^*(n) < F(\omega_v) < p$*, the ex-ante voter welfare is higher in the absence of the media; (2) when* $1/2 < F(\omega_v) < k^*(n)$*, there exists* $F(\omega_v) < \hat{p}(n, F(\omega_v)) < \tilde{p}(n, F(\omega_v)) < 1$ *such that for* $p \in (F(\omega_v), \hat{p}(n, F(\omega_v))) \cup (\tilde{p}(n, F(\omega_v)), 1)$*, the ex-ante voter welfare is higher in the absence of the media. However, when* $p \in (\hat{p}(n, F(\omega_v)), \tilde{p}(n, F(\omega_v)))$*, the ex-ante voter welfare is higher when the media is present.*

Consider the case when the prior distribution is biased in favor of the alternative X. In this case if the signal strength of the voters is sufficiently low, then the media chooses not to transmit any information and the resultant equilibrium (both in the presence and absence of the media) is such that each voter votes X irrespective of his private signal. It therefore follows that the social decision is unanimously chosen to be X and this is invariant to the number of voters. Hence the ex-ante voter welfare is the same whether or not a media is present.

If the signal strength is sufficiently high, then the proposition states that ex-ante voter welfare is higher in the absence of a media for a sufficiently large size of the electorate. The reason is as follows: In the presence of a media, the nature of information provided is such that the voters invariably vote for their less preferred alternative (X) when $\omega \in (\omega_v, \omega^*]$.

However, they surely vote for their preferred alternative (X) when $\omega \in [0, \omega_v]$. Now, consider the scenario where the media is absent, in which case each voter votes according to his own signal. The probability $J(n, p)$ of a correct decision rises as the number of voters increase, since the incidences of informative signals that contribute to the social decision rises. Hence the relative advantage the presence of a media has on voter welfare when $\omega \in [0, \omega_v]$ diminishes as the size of the electorate rises, due to the fact that owing to the large volume of informative private signals aggregated it becomes highly likely that the preferred alternative (X) in this range would be the social decision anyway. When $\omega \in (\omega_v, \omega^*]$, (which is the zone of incorrect decision-making under the media), by the same logic it follows that the preferred alternative (Y) in this range would be the social decision in the no media case as the size of the constituency rises. Hence the ex-ante voter welfare under no media exceeds that under a media.

Now consider the case when the size of the electorate is sufficiently small. In this case the probability of a correct decision (without media when voters vote according to their private signals) is low, due to the low number of informative signals that are aggregated to form the social decision. We explain the welfare comparison in this case by a numerical example.

Example 1. Suppose $F(\omega_v)$ is a uniform distribution with support $[0, 1]$. Let the number of voters be $n = 3$. It follows that in this case, if $k^*(3) \approx .527 < \omega_v < p$, then the ex-ante voter welfare is always higher under no media. Since the prior distribution is such that for the majority of the states the preferred alternative of the media and the voters coincide, the media uses this to manipulate the voters such that the voters are better-off on their own without the media. The reasoning is completed by highlighting the fact that in this case $p > \omega_v$, which means we are commenting on the scenario where the strength of the private signals of the voters is high. Let $1/2 < \omega_v = .51 < .527$. When $p \in (.51, \hat{p}(3) \approx .52197)$ or $p \in (\tilde{p}(3) \approx .68804, 1]$, the ex-ante voter welfare is higher in the absence of the media, while for $p \in (.52197, .68804)$ the ex-ante voter welfare is higher under a media.

Note from Lemma 7 that when the voters have a high level of awareness, ω^* is a decreasing function of p. This implies the region over which the media is able to manipulate the voters into voting for their less preferred choice decreases as the strength of their private signal rises. This means when p is low the zone of manipulation $(\omega_v, \omega^*]$ under the media is large, so that the voter welfare is higher in the absence of the media. On the other hand, if p is very high, the probability that the voters will collectively choose the preferred alternative without a media is high for all states, and hence higher voter welfare again warrants non-interference from the media. However, for an intermediate range of p, the presence of a media (yielding an advantage in the form of a guarantee that the social decision will be the most preferred one for the voters when $\omega \in [0, \omega_v]$) dominates, such that the ex-ante voter welfare is higher under a media relative to the case when the media is absent.

The intermediate range of signal precision for which the presence of the media is desirable for voter welfare shrinks as the size of the electorate rises from three to five. The logic behind the result is the following: the ex-ante voter welfare without the media increases as the size of the electorate goes up, while the ex-ante voter welfare under media presence is invariant to the number of voters. Hence the zone where the absence of media is relatively more advantageous for voter welfare goes up as the size of the electorate rises, which alternatively implies that the zone where the presence of the media is preferable for achieving higher voter welfare shrinks.

The following proposition deals with the last case to be considered where the prior distribution is biased in favor of Y. There may still arise cases when additional information available from the media may hurt voter welfare, while in others additional information augments voter welfare.

Proposition 5 (Welfare under Large Conflict: $F(\omega_v) < 1/2$)**.** *In a scenario with $n \geq 3$ voters, the presence of a media with large conflict may or may not enhance ex-ante welfare. In particular,*

(a) Let $1 - p < F(\omega_v)$. If $(*)$ is satisfied, then ex-ante voter welfare is higher in the presence of the media iff $F(\omega_v) < \frac{p}{1-p}(1 - J(n,p))$. If $(*)$ is violated, then the ex-ante voter welfare is always higher in the presence of the media.

(b) Let $F(\omega_v) < 1 - p$. In this case the presence of the media always corresponds to higher ex-ante welfare for the voter.

Consider the case of a sufficiently aware society where each voter votes according to his private signal in the absence of the media. As discussed before, $(*)$ is always satisfied for all $p \in (\frac{1}{2}, 1)$ when $n \to \infty$, in which case we have $J(n,p) = 1$. Since $F(\omega_v) > 0$, it follows that $F(\omega_v) > \frac{p}{1-p}(1 - J(n,p))$ and thus if the size of the electorate is very large, ex-ante voter welfare is higher in the absence of the media. This is because of the following: in the media's presence the probability of a correct decision is invariant to the number of voters since each of them follows a signal invariant (or pooling) voting strategy where the decision is always unanimous. In its absence the voters vote according to their private signals which implies that the large number of private signals aggregated to form the social decision guarantees that the correct social decision will be arrived at with a very high probability. Thus for a very large electorate, the presence of a manipulative media hurts welfare.

If however, the size of the electorate is low, then whether the presence of the media leads to higher ex-ante welfare or not depends on the 'relative size' of the set of states for which decision-making is improved owing to the information provided by the media vis a vis the set of states over which the voters are manipulated to vote for their less favored alternative. This in turn is compared to the scenario where the media is absent. Both the cases where media presence or absence is desirable for higher ex-ante voter welfare is feasible, which we demonstrate by citing two examples where the number of voters is low and $(*)$ holds.

Example 2 (*Condition* $(*)$ *holds, media presence improves welfare*)**.** For the first example, let $F(\omega_v) = .35$, $p = .66$ and $n = 3$. It is already shown after Lemma 8 that $(*)$ is satisfied for these values of the parameters. For these values, $\frac{p}{1-p}(1 - J(n,p)) \approx .521 > .35 = F(\omega_v)$, and hence in this case the presence of the media leads to higher ex-ante voter welfare.

Example 3 (*Condition* $(*)$ *holds, media presence hurts welfare*)**.** Let $F(\omega_v) = .48$, $p = .74$ and $n = 3$. In this case the conditions $\frac{1}{3} < F(\omega_v) < \frac{1}{2}$ and $1 - F(\omega_v) < p \leq \frac{1+F(\omega_v)}{2}$ holds, and hence $(*)$ is valid which is checked by noting that corresponding to these values, $(Q(n,1;\omega_v) - 1) \approx -.083 < 0$. However, in this case $\frac{p}{1-p}(1 - J(n,p)) \approx .477 < .48 = F(\omega_v)$, and hence in this case the absence of the media leads to higher ex-ante voter welfare.

Now consider the case where $(*)$ is violated, an example of which has been provided after Lemma 8. In this case, due to transmission of news by the media, the voters follow a signal invariant strategy of voting X for a certain range of states contained entirely in $[0, \omega_v]$, which is their preferred alternative for these states of the world. For the rest of the states the voters vote according to their private signals, which they would have done anyway even in the absence of the media. Hence ex-ante voter welfare is higher in the presence of the media when $(*)$ is violated. Now consider the case where the precision of signals of the voters is sufficiently low such that in the media's absence the voters vote for Y irrespective of their signal received. Since the states where the preferred alternative of the media and the voters are different are more likely to occur given the prior distribution, the power of the media to manipulate the voters is limited, and given this the voter welfare is higher if information from the media is received.

A summary of all results of this section can be found in Table 1.

We now discuss some other aspects and implications of this model.

4.4.2 Voting versus Delegation

In a cheap talk setting with a single receiver, Dessein (2002) shows that full delegation of decision making rights to the informed sender is better than cheap talk communication if the degree of conflict is not large. In a similar setting Ivanov (2010) studies the case where it is now possible to limit the degree of precision of the expert's information, but not the content. The paper studies the welfare effects of information transmission versus directly delegating the expert to take the decision to show that it may not be in the best interest of the principal to delegate authority to the most informed subordinate.

In relation to these two works, an important feature of our multiple-receiver model is that under no circumstances can it be better for the voters to give up their rights to vote and delegate decision making authorities to the media or the informed elite. To see this first note that if the media becomes the DM, then the social decision is X and

	Small Conflict: $F(\omega_v) > 1/2$		**Large Conflict: $F(\omega_v) < 1/2$**	
Media Activity and Influence	**Unaware Society** $p < F(\omega_v)$	**Aware Society** $p > F(\omega_v)$	**Unaware Society** $p < 1 - F(\omega_v)$	**Aware Society** $p > 1 - F(\omega_v)$
Nature of News	Babble	- Informative news - Inconclusive slant in favour of X - Fully revealing slant in favour of Y	- Informative news - Inconclusive slant in favour of X - Fully revealing slant in favour of Y	(a) If (*) holds: - Informative news - Inconclusive slant in favour of X - Fully revealing slant in favour of Y (b) If (*) does not hold: - Informative news - Fully revealing slant in favour of X - Inconclusive slant in favour of Y
Impact on Voting	Each voter votes for X	Voters always vote for media slants	(a) If $n > 3$ or if $n = 3$, $p < 0.76$, then voters always vote for media slants (b) If $n = 3$, $p > 0.76$ then - Voters ignore X slant and vote according to their private information - Voters follow the Y slant	(a) If (*) holds: Voters always vote for media slants (b) If (*) does not hold: - Voters follow the X slant - Voters ignore the Y slant and vote according to their private information
Impact on Welfare	No impact	Media presence can hurt	Media always helps	(a) If (*) holds: Media presence can hurt (b) If (*) does not hold: Media always helps.

Table 1: A summary of all results with Voting

the expected payoff of each voter is simply $F(\omega_v)\tau + (1 - F(\omega_v))\zeta$. Suppose first that $F(\omega_v) > 1/2$. If $p < F(\omega_v)$ then we have shown that the outcome from voting is X independent of whether there is a reputation driven media or not. Hence, in this case delegation to the media cannot help the voters. If $p > F(\omega_v)$, then the payoff of the voter in the absence of a media is simply $J(n,p)\tau + (1 - J(n,p))\zeta$ which is higher than $F(\omega_v)\tau + (1 - F(\omega_v))\zeta$, the voter's payoff from delegation, if and only if $J(n,p) > F(\omega_v)$. But for any $n > 1$ and any $p > 1/2$ we have $J(n,p) > p$, and since $p > F(\omega_v)$ it follows that for any $n \geq 3$ and any $p > 1/2$ we have $J(n,p) > F(\omega_v)$. Hence delegation cannot be first best. Now suppose $F(\omega_v) < 1/2$. In this case when $p > 1 - F(w_v)$, then in the absence of a media the voting equilibrium is separating. In this case, democracy beats delegation if $J(n,p) > F(w_v)$, which always holds since $J(n,p) > 1/2 > F(w_v)$. When $p < 1 - F(w_v)$, then in the absence of a media the the voting equilibrium is pooling (on alternative Y) so that voter's payoff is given by $F(w_v)\zeta + (1 - F(w_v)\tau$ while under delegation it is given by $F(w_v)\tau + (1 - F(w_v))\zeta$. Since $F(w_v) < 1/2$, the welfare with no media beats welfare under delegation. Hence, in no circumstance can the society be better off by delegating decision making authorities to the media.

4.4.3 Media Regulation

We have established that media presence can hurt. This result suggests interesting policy implications. To address this, it is more convenient to re-interpret the model slightly. Suppose for the moment that the voters can neither avoid the media nor directly punish it for transmitting misleading news. However, there is a regulatory authority that potentially can penalize the media. If it decides to impose a fine (like cancellation of telecast rights) for misleading news, and if this is common knowledge, then the model studied above can be readily used to ask what the authority should do.

Observe that if the media is not regulated in this sense, it resembles the case when no information can be transmitted credibly (that is, absence of a reputed media). Our results suggest in certain circumstances (characterized by p, F and n), the optimal policy is then either to ban the media outright (so that it cannot transmit any news) or deregulate it completely (so that it cannot credibly transmit any information even if it tried). Since banning the media is most of the time politically infeasible, deregulation is the only option. By deregulating, the authority takes away credibility of the media and our results show this can be beneficial.

Of course, our results also suggest that under certain other circumstances when media presence helps the voters, the authorities should strengthen regulatory punishments.

4.4.4 Reputation-building and endogenous viewership

Fix viewership first to n. If the media is aware that by gaining in reputation it can improve its own payoffs, it is fair to say that some sort of truthful reporting should appear in a repeated setting. By subsequently reporting truthful news, the media builds the credibility of future news. Interestingly, under certain values of p and F the ex-ante welfare of the voters in each period is lower in this scenario, when compared to the case where the media was not engaged in an effort to build a reputation through truthful reporting.

Further, if media's presence can hurt the voters, can the voter choose to stay away from media news? Durante and Knight (2012) examines whether and how viewers in Italy respond to changes in partisan bias in media news. They find robust evidence that viewers responded to these changes by modifying their choice of favorite news programs.

So consider the scenario where the viewership of news is decentralized in the sense that each of the voters endogenously choose whether to access the news transmitted by the media. In our setup, full participation in the acquisition of news is the unique Nash equilibrium, which then becomes equivalent to the model we study. This is because ceteris paribus, as our analysis of a single DM reveals, more information always increases that voter's expected payoff. This coupled with the fact that in a multi-player scenario each voter votes as-if-pivotal would mean that each voter will always be willing to improve his information prior to voting.

4.5 Discussion of Assumptions

Our model may also be re-investigated in a more general setting by considering the following: firstly, we have considered a scenario where each of the voters get a binary signal that depend on the range in which the true state belongs. An alternative set-up where the voters receive informative signals regarding the underlying state of the world may be studied. This would alter the results quantitatively. However, given the nature of strict preferences over the alternatives the voters share for every state of the world, the fundamental manner in which the behaviour of the voters has been modelled (which is that the voter aggregates all information to ascertain which alternative will yield him the higher expected pay-off) remains the same. The second possible modification is the following: in our model, we look into the scenario where there is a discrete switch in the preferences of the voters (in the sense that when the state is lower than or equal to w_v, the voters prefer alternative X, while for all states above w_v they prefer Y). This assumption maintains the characteristic of standard jury models that the voters have strict preference over the alternatives for every state of the world. We may alternatively consider the following case: suppose the pay-off of the voters from the alternative X is decreasing as the state increases, while the pay-off of the voter from the alternative Y is increasing as the state increases. When the state is lower than w_v, the voters prefer X, for all states higher than w_v, the voters prefer Y, while they are indifferent between X and Y when the state is w_v. This modification again will quantitatively alter the results, but the basic process in which the behaviour of the voters and the media works in our model will be the same. In our model, we have assumed that the media can pre-commit to the signalling technology before observing the state. We may consider the scenario where the media announces the signalling technology *after* observing the state. In this case the most influential message strategy will be changed according to the observed state by the media. For a media which is not driven by reputation, it cannot credibly commit to announce any signalling technology with the guarantee that the true state will necessarily be contained in the interval that is declared to the voters. In this scenario, no information can be transmitted.

Lastly, one may also investigate how the results are altered if we consider a multiple alternatives voting model and/or apply other aggregation rules such as the system of approval voting or cumulative voting. It is also quite natural to introduce multiple media outlets with either like or conflicting biases (in a set-up similar to Krishna and Morgan (2001), Gilligan and Krehbiel (1989)) who may either sequentially or simultaneously deliver messages to the voters, and examine their implication on public welfare. We reserve this for future research.

Summarising, we may say the following: in the model described in Chapter 4, we study the effect of information transmission by a perfectly informed and partially biased media to less informed voters. We show that the presence of media never hurts welfare if there is a single decision maker or when multiple voters are present with low awareness levels. If the voters are sufficiently aware, then media presence hurts welfare for large electorates. The strategically chosen content of the informative news transmitted by the media overpowers the private information of the voters and invariably makes them vote for a particular alternative. In contrast, without the media the voters would have voted according to their private signals so that the probability of the correct decision increases with the size of the constituency. Hence media absence can improve welfare in large constituencies. This perverse effect of media presence can also appear in small constituencies, though not universally. Needless to mention, our work is not to suggest that media is not useful. As our results show, in many instances they are.

4.6 Chapter Appendix

4.6.1 Notations and formal definitions

Fix the arity of the message strategy to k. A perfect Bayesian equilibrium (PBE) is a strategy profile (m_k, v) such that:

(i) for each $s_i \in \{X, Y\}$, and $i \in I$ we have

$$\sum_{s_{-i}\in\{X,Y\}^{n-1}} \left(\int_{\omega\in\Omega_k} \mathbf{P}[s_{-i}|m_k(\omega), s_i] u(\delta(v(m_k(\omega), (s_i, s_{-i}))), \omega) f(\omega|s) d\omega \right) \geq$$
$$\sum_{s_{-i}\in\{X,Y\}^{n-1}} \left(\int_{\omega\in\Omega_k} \mathbf{P}[s_{-i}|m_k(\omega), s_i] u(\delta(v_i'(m_k(\omega), (s_i, s_{-i}))), v_{-i}, \omega) f(\omega|s) d\omega \right),$$

and

(ii) for each realized state $\omega \in \Omega$ and each $\omega' \notin \Omega(m_k(\omega))$, we have

$$\sum_{s \in \{X,Y\}^n} \mathbf{P}[s|\omega] u_m(\delta(v(m_k(\omega), s)), \omega) \geq \sum_{s \in \{X,Y\}^n} \mathbf{P}[s|w] u_m(\delta(v((m_k(\omega')), s)), \omega) - c.$$

Given two equilibria (m_k, v) and $(m_{k'}, v')$, we say that they are *decision-equivalent* if for every $\omega \in \Omega$, $v(m_k, s) = v'(m_{k'}, s)$. We say (m_k, v) is *decision-equivalent coarsening* (DEC) of $(m_{k'}, v')$ if they are decision equivalent and $k < k^{'}$. We shall always work with maximal DECs, that is, given the set of all decision equivalent equilibria, we shall only consider those which are the coarsest in this set.

In the voting sub-game an equilibrium is *pooling* when $v_i(m_k(\omega), s_i) = v_j(m_k(\omega), s_j)$ for any $i, j \in I$ for any $s_i, s_j \in \{X, Y\}$. Similarly an equilibrium is *separating* when $v_i(m_k(\omega), X) \neq v_i(m_k(\omega), Y)$ for any $i \in I$.

Let Ξ be the set of all possible informative equilibria. An informative equilibrium $(m_k^*, v^*) \in \Xi$ is called *most influential* if for all equilibria $(m_k, v) \in \Xi$, we have

$$\int_{\omega \in \Omega} \left(\sum_{s \in \{X,Y\}^n} \mathbf{P}[s|\omega] u_m(\delta(v^*(m_k^*(\omega), s)), \omega) \right) f(\omega) d\omega$$
$$\geq \int_{\omega \in \Omega} \left(\sum_{s \in \{X,Y\}^n} \mathbf{P}[s|\omega] u_m(\delta(v(m_k(\omega), s)), \omega) \right) f(\omega) d\omega.$$

We identify social welfare in terms of the *ex-ante welfare* of the voters prior to any non-prior information received. Note that this is fully explained by any individual voter's preferences since all voters are ex-ante identical and each represents the preferences of the public. Let $U(m_k, v)$ be the *ex-ante welfare of a single voter* under a strategy profile (m_k, v). Then

$$U(m_k, v) = \int_{\omega \in \Omega} \left(\sum_{s \in \{X,Y\}^n} \mathbf{P}[s|\omega] u(\delta(v(m_k(\omega), s)), \omega) \right) f(\omega) d\omega.$$

4.6.2 Proofs

Proof of Lemma 3 :

Let $\gamma_{s_i} = \mathbf{P}[\omega \leq \omega_v | s_i]$. In the absence of the media, let the expected utility of the voter i from voting v_i when he receives a private signal of s_i be denoted by $U_{v_i}(\emptyset, s_i)$. The voter i votes for X if and only if $U_X(\emptyset, s_i) > U_Y(\emptyset, s_i)$, from which it follows that $(2\gamma_{s_i} - 1)\tau > (2\gamma_{s_i} - 1)\zeta$. Since $\tau > \zeta$, the above inequality holds if and only if $(2\gamma_{s_i} - 1) > 0$, which implies $\gamma_{s_i} > 1/2$. Hence it follows that $v_i(\emptyset, X) = X$ if $\gamma_X > 1/2$ and $v_i(\emptyset, X) = Y$ if $\gamma_X < 1/2$. Similarly, $v_i(\emptyset, Y) = X$ if $\gamma_Y > 1/2$ and $v_i(\emptyset, Y) = Y$ if $\gamma_Y < 1/2$.

Consider $F(\omega_v) > 1/2$. In this case the condition $\gamma_X > 1/2$ implies $p > 1 - F(\omega_v)$, which always holds since $p > 1/2$. The condition $\gamma_Y < 1/2$ implies $p > F(\omega_v)$. The binding condition for $v_i(\emptyset, s_i) = X$ for each $s_i \in S$ is therefore $p > F(\omega_v)$. This proves part (a.i) of the lemma. Note that when $p < F(\omega_v)$, then $\gamma_X > 1/2$ and $\gamma_Y > 1/2$. This proves part (a.ii) of the lemma.

Now consider $0 < F(\omega_v) < 1/2$. In this case the condition $\gamma_Y < 1/2$ implies $p > F(\omega_v)$, which always holds since $F(\omega_v) < 1/2 < p$. The condition $\gamma_X > 1/2$ implies $p > 1 - F(\omega_v)$, which is therefore the binding condition for $v_i(\emptyset, s_i) = s_i$ for each $s_i \in S$. This proves part (b.i) of the lemma. Note that when $p < 1 - F(\omega_v)$, then $\gamma_Y < 1/2$ and $\gamma_X < 1/2$ holds. This proves part (b.ii) of the lemma and concludes the proof.

Proof of Lemma 4 :

When $1/2 < p < F(\omega_v)$, from Lemma 3 part (a.ii) it follows that in the voting subgame of the informative equilibrium the voting strategy v_i is such that the preferred alternative of the media is implemented for all states $\omega \in [0, 1]$, and hence there does not exist any profitable deviation for the media from $\omega^* = 1$. This proves part (a) of the lemma.

Let $1/2 < F(\omega_v) < p$. Consider the equilibria under following class of message strategy with arity $k = 2$, which we classify as *Class 1*, under which $\Omega_1 = [0, \hat{\omega})$, $\Omega_2 = [\hat{\omega}, 1]$, where $\omega_v < \hat{\omega}$ such that $v_i(m_1, s_i) = X$ and $v_i(m_2, s_i) = Y$ for each $s_i \in S$.

Suppose the message provided is m_1. In this case voter i considers the following posterior probability given by

$$\gamma'_{s_i} = \mathbf{P}[\omega < \omega_v | s_i, m_1] = \frac{G}{H},$$

where

$$G = \mathbf{P}[s_i, m_1 | \omega < \omega_v,]\mathbf{P}[\omega < \omega_v]$$

and

$$H = \mathbf{P}[s_i, m_1 | \omega < \omega_v]\mathbf{P}[\omega < \omega_v] + \mathbf{P}[s_i, m_1 | \omega_v < \omega < \hat{\omega}]\mathbf{P}[\omega_v < \omega < \hat{\omega}]$$

Voter i votes $v_i(m_1, s_i) = X$ iff $\gamma'_{s_i} > 1/2$, and $v_i(m_1, s_i) = Y$ otherwise. We have,

$$\gamma'_X = \frac{pF(\omega_v)}{pF(\omega_v) + (1-p)(F(\hat{\omega}) - F(\omega_v))}$$

and

$$\gamma'_Y = \frac{(1-p)F(\omega_v)}{(1-p)F(\omega_v) + p(F(\hat{\omega}) - F(\omega_v))}.$$

Note that $\gamma'_Y = 1/2$ when $F(\hat{\omega}) = \frac{F(\omega_v)}{p}$. Since $\frac{\partial \gamma'_Y}{\partial F(\hat{\omega})} < 0$, it follows that when $F(\hat{\omega})$ is greater (lesser) than $\frac{F(\omega_v)}{p}$, then γ'_Y is lesser (greater) than 1/2. Since $p > 1/2$, we have $\gamma'_{s_i=X} > \gamma'_{s_i=Y}$. Therefore when $\Omega_1 = [0, \hat{\omega}]$ where $F(\hat{\omega}) = \frac{F(\omega_v)}{p}$ is satisfied, the voter votes $v_i = X$ for each $s_i \in S$ in a symmetric informative equilibrium. For the case when $m_2 = (\hat{\omega}, 1]$, it follows that $\mathbf{P}[\omega \leq \omega_v | m_2, s_i] = 0$ for each $s_i \in S$, and hence in an informative equilibrium the voter i votes $v_i = Y$ for each $s_i \in S$. This proves that (m_k, v) is an equilibrium.

Note that in this case the ex-ante payoff of the media under *Class 1* message strategy is given by

$$\mathbf{E}[u_m]_1 = \int_0^{\hat{w}} \tau_m f(\omega) d\omega + \int_{\hat{w}}^1 \zeta_m f(\omega) d\omega$$

which simplifies as

$$\mathbf{E}[u_m]_1 = F(\hat{w})(\tau_m - \zeta_m) + \zeta_m$$

Since $\tau_m > \zeta_m$, it follows that $\frac{\partial \mathbf{E}[u_m]_1}{\partial \hat{w}} > 0$, which implies that by choosing $\hat{w}$ that satisfies the condition $F(\hat{w}) = \frac{F(\omega_v)}{p}$, the ex-ante payoff of the media is maximized under *Class 1* message strategies. Hence the optimum value of ex-ante payoff of the media under Class 1 message strategies is given by

$$\mathbf{E}[u_m]_1^* = \frac{F(\omega_v)}{p}(\tau_m - \zeta_m) + \zeta_m \tag{4.1}$$

Consider the equilibria in the following class of message strategies, defined as *Class 2*.

Class 2: Suppose there exists $\alpha \in [0, \omega_v)$, $\beta \in (\omega_v, 1]$ such that the message strategy function m_k followed by the reputation driven media is such that $\Omega_1 = [0, \alpha)$, $\Omega_2 = [\alpha, \beta)$, $\Omega_3 = [\beta, 1]$, where the voting strategy followed is:

$$v_i = \begin{cases} X & \text{if } \Omega_1 = [0, \alpha) \\ s_i & \text{if } \Omega_2 = [\alpha, \beta] \\ Y & \text{otherwise} \end{cases}$$

Note that when $m_2 = (\alpha, \beta]$ is received, then in an informative and symmetric equilibrium for $v_i = s_i$ for each $s_i \in S$ to hold, the conditions

$$\hat{\gamma}_X = \mathbf{P}[\omega \le \omega_v | s_i = X, m_2 = (\alpha, \beta]] > 1/2$$

and

$$\hat{\gamma}_Y = \mathbf{P}[\omega \le \omega_v | s_i = Y, m_2 = (\alpha, \beta]] < \frac{1}{2}$$

need to be satisfied simultaneously. The first inequality reduces to

$$\frac{p}{1-p}(F(\omega_v) - F(\alpha)) + F(\omega_v) > F(\beta)$$

while the second becomes

$$\frac{1-p}{p}(F(\omega_v) - F(\alpha)) + F(\omega_v) < F(\beta).$$

Under this class the ex-ante payoff of the media is denoted by $\mathbf{E}[u_m]_2$ where

$$\mathbf{E}[u_m]_2 = \int_0^{\alpha} \tau_m f(\omega) d\omega + \int_{\alpha}^{\omega_v} (p\tau_m + (1-p)\zeta_m) f(\omega) d\omega + \int_{\omega_v}^{\beta} ((1-p)\tau_m + p\zeta_m) f(\omega) d\omega + \int_{\beta}^{1} \zeta_m f(\omega) d\omega$$

which is simplified as

$$\mathbf{E}[u_m]_2 = (F(\alpha) + F(\beta))(1-p)(\tau_m - \zeta_m) + F(\omega_v)(\tau_m - \zeta_m)(2p-1) + \zeta_m \tag{4.2}$$

Since $\tau_m > \zeta_m$ and $1/2 < p < 1$, from (4.2) it follows that in order to maximize the ex-ante payoff of the media, the following maximization problem needs to be solved, which we denote as $(*)$.

Maximize $(F(\alpha)+F(\beta))$ subject to: (i) $\frac{p}{1-p}(F(\omega_v)-F(\alpha))+F(\omega_v) > F(\beta)$, (ii) $\frac{1-p}{p}(F(\omega_v)-F(\alpha)) + F(\omega_v) < F(\beta)$, (iii) $0 \leq F(\alpha) < F(\omega_v)$, and (iv) $F(\omega_v) < F(\beta) \leq 1$.

Setting $F(\alpha) = 0$ and considering equality in constraint (i), we have $F(\beta) = \frac{F(\omega_v)}{1-p}$. Note that since $p > 1/2$ and $F(\omega_v) > 1/2$, therefore the condition $1 \geq \frac{F(\omega_v)}{1-p}$ can never hold. Now consider $1 < \frac{F(\omega_v)}{1-p}$. In this case from the optimization problem $(*)$ it follows that the optimum value is given by the relation $F(\beta^*) = 1$, which implies $\beta^* = 1$. Putting the optimum value of $F(\beta^*)$ in constraint (i), we have $F(\alpha^*) = \frac{F(\omega_v)}{p} - \frac{1-p}{p}$. Replacing the optimum values of $F(\alpha^*)$ and $F(\beta^*)$ in (4.2), we have the maximum ex-ante payoff of the media under equilibria belonging to Class 2 to be

$$\mathbf{E}[u_m]_2^* = \left(\frac{F(\omega_v)}{p} - \frac{1-p}{p} + 1\right)(1-p)(\tau_m - \zeta_m) + F(\omega_v)(\tau_m - \zeta_m)(2p-1) + \zeta_m \quad (4.3)$$

After having described the equilibria which corresponds to the highest ex-ante payoff of the media in Class 1 and Class 2 for the single receiver case, we compare the ex-ante payoff of the media between these two equilibria. From (4.1) and (4.3) it follows that

$$\mathbf{E}[u_m]_2^* - \mathbf{E}[u_m]_1^* = \frac{E}{p} \quad (4.4)$$

where $E = (\tau_m - \zeta_m)(2p^2(F(\omega_v) - 1) + p(3 - 2F(\omega_v)) - 1)$

Since $\tau_m > \zeta_m$, we have $\mathbf{E}[u_m]_2^* - \mathbf{E}[u_m]_1^* < 0$ if

$$2p^2(F(\omega_v) - 1) + p(3 - 2F(\omega_v)) - 1 < 0 \quad (4.5)$$

Let $D(p, F(\omega_v)) = 2p^2(F(\omega_v)-1)+p(3-2F(\omega_v))-1$. Note that $\frac{\partial D(p,F(\omega_v))}{\partial F(\omega_v)} = 2p(p-1) < 0$. Therefore the maximum value of $D(p, F(\omega_v))$ is attained at $D(p, 1/2) = -(p-1)^2 < 0$. Hence $D(p, F(\omega_v)) < 0$ for all $p \in (1/2, 1)$, $F(\omega_v) \in (1/2, 1)$. This proves that for the single voter case, the optimal equilibrium obtained under Class 1 corresponds to a higher level of ex-ante payoff for the media than the optimal equilibrium obtained under Class 2.

We now argue that the optimum equilibrium obtained under Class 1 corresponds to the maximum ex-ante payoff of the media among all possible equilibria. Note that under Class 1 equilibria, $\mathbf{E}[u_m]_1$ is increasing in $\hat{w}$, and the maximum value of $\hat{w}$ under Class 1 is when the condition $F(\hat{w}) = \frac{F(\omega_v)}{p}$ is satisfied. When $F(\hat{w}) > \frac{F(\omega_v)}{p}$ then $\gamma_Y^{'} < 1/2$ and we revert to equilibria under Class 2 with $\alpha = 0$, $\beta = \hat{w}$ which has been proved to have a lower expected payoff for the media than the optimum Class 1 equilibrium. This proves part (b) and concludes the proof.

Proof of Lemma 5 :

Now consider the case when a media is present when $F(\omega_v) < 1/2$.

Analogous to the proof of Lemma 4, it follows that the most influential equilibria under Class 1 type of message strategies is achieved by choosing $\hat{\omega}$ such that the condition $F(\hat{\omega}) = \frac{F(\omega_v)}{p}$ is satisfied. Under this class the expected utility of the media is given by (4.1).

Now we consider Class 2 type of message strategies which gives rise to optimization problem $(*)$ as defined in the proof of Lemma 4 part (b). Let $p > 1 - F(\omega_v)$, which implies $F(\omega_v) > 1 - p$. In this case, analogous to the proof of Lemma 4, it follows that β^* and α^* are such that $F(\beta^*) = 1$ and $F(\alpha^*) = \frac{F(\omega_v)}{p} - \frac{1-p}{p}$. Hence the expression for $\mathbf{E}[u_m]_2^* - \mathbf{E}[u_m]_1^*$ for this case is given by (4.4). Consider the expression $D(p, F(\omega_v))$ as defined in the proof of Lemma 4. From (4.4) it follows that $\mathbf{E}[u_m]_2^*$ is greater (lesser) than $\mathbf{E}[u_m]_1^*$ if $D(p, F(\omega_v))$ is positive (negative). Note that $D(1, F(\omega_v)) = 0$ and $\frac{\partial D(p,F(\omega_v))}{\partial p}|_{p=1} = 2F(\omega_v) - 1 < 0$, since $F(\omega_v) < 1/2$. Also note that $D(1/2, F(\omega_v)) = -\frac{F(\omega_v)}{2} < 0$ and $\frac{\partial D(p,F(\omega_v))}{\partial p}|_{p=1/2} = 1 > 0$. The expression $D(p, F(\omega_v)) = 0$ has a unique solution in $p \in (1/2, 1)$ that is given by $\bar{p} = \frac{1}{2(1-F(\omega_v))}$. This proves that for all p lesser (greater) than $\bar{p}$, the expression $D(p, F(\omega_v))$ is negative (positive). Now, if the condition $1 - F(\omega_v) < p < \bar{p} = \frac{1}{2(1-F(\omega_v))}$ has to hold, we must have $1 - F(\omega_v) < \frac{1}{2(1-F(\omega_v))}$ which holds iff $F(\omega_v) > \left(1 - \frac{1}{\sqrt{2}}\right) \approx .29$. Hence if $F(\omega_v) \leq .29$, then $\frac{1}{2(1-F(\omega_v))} \leq 1 - F(\omega_v) < p$ and $D(p, F(\omega_v)) > 0$ always holds. This proves part (a.i). However, if $F(\omega_v) > .29$, then if $1 - F(\omega_v) < p < \bar{p}$, we have $D(p, F(\omega_v)) < 0$ but if $1 - F(\omega_v) < \bar{p} < p$, then $D(p, F(\omega_v)) > 0$. This proves part (a.ii) of the lemma.

Now consider $p < 1 - F(\omega_v)$. In this case the solution of optimization problem $(*)$ is given by α^* and β^* such that $F(\alpha^*) = 0$ and $F(\beta^*) = \frac{F(\omega_v)}{1-p}$. Putting α^* and β^* in (4.2) we have the ex-ante payoff of the media corresponding to the most influential message strategy under $Class2$ to be

$$\mathbf{E}[u_m]_2^* = \left(\frac{F(\omega_v)}{1-p}\right)(1-p)(\tau_m - \zeta_m) + F(\omega_v)(\tau_m - \zeta_m)(2p-1) + \zeta_m \tag{4.6}$$

From (4.1) and (4.6) we have

$$\mathbf{E}[u_m]_2^* - \mathbf{E}[u_m]_1^* = \frac{F(\omega_v)(\tau_m - \zeta_m)(2p^2 - 1)}{p}$$

Since $F(\omega_v) > 0$, $\tau_m > \zeta_m$, it follows that $\mathbf{E}[u_m]_2^*$ is lesser (greater) than $\mathbf{E}[u_m]_1^*$ if p is lesser (greater) than $\frac{1}{\sqrt{2}}$. This proves parts (b.i) and (b.ii) of the lemma and concludes the proof.

Proof of Proposition 3 :

When $1/2 < p < F(\omega_v)$, from Lemma 3 case (a.ii) and Lemma 4 case (a) it follows that under no media or with media the ex-ante welfare of the DM is

$$U(\emptyset, v) = F(\omega_v)\tau + (1 - F(\omega_v))\zeta$$

This proves part (a.i) of the proposition.

When $1/2 < F(\omega_v) < p$, then from Lemma 3 part (a.i) it follows that

$$U(\emptyset, v) = p\tau + (1-p)\zeta \tag{4.7}$$

In the presence of the media it follows from Lemma 4 part (b) that in the most influential informative equilibrium, the ex-ante welfare of the DM is

$$U(m_k, v) = \tau + F(\omega_v)(\tau - \zeta)\left(\frac{p-1}{p}\right) \tag{4.8}$$

From (4.7) and (4.8) it follows that $U(m_k, v) - U(\emptyset, v) > 0$ iff

$$(p-1)(F(\omega_v) - p) > 0 \tag{4.9}$$

which always holds since $F(\omega_v) < p < 1$. This proves part (a.ii) of the proposition.

Now consider $F(\omega_v) < 1/2$.

When $p > 1 - F(\omega_v)$, then from Lemma 3 part (b.i) it follows that in the absence of the media, the ex-ante voter welfare is given by (4.7). Now consider presence of the media. In the instances when the optimal Class 1 message is delivered, the ex-ante welfare of the voter is given by (4.8). Since $F(\omega_v) < 1/2 < p < 1$, therefore (4.9) always holds, and hence $U(m_k, v) - U(\emptyset, v) > 0$ in this case. In the instances when optimal Class 2 message is provided by the media, it is easy to check that $U(m_k, v) - U(\emptyset, v) > 0$, since in the absence of the media the DM always votes according to his private signal, while in its presence he votes according to his signal for $\omega \in [\omega^*, 1]$, while being guaranteed of his most preferred alternative X when $\omega \in [0, \omega^*)$. This proves part (b.i) of the proposition.

Suppose $p < 1 - F(\omega_v)$, then from Lemma 3 part (b.i) it follows that the ex-ante welfare of the DM is given by

$$U(\emptyset, v) = F(\omega_v)\zeta + (1 - F(\omega_v))\tau \tag{4.10}$$

In the presence of a media it follows from Lemma 5 part (b.i) that if $p < \frac{1}{\sqrt{2}}$, then in the most influential informative equilibrium, the ex-ante welfare of the DM is given by equation (4.8). From (4.8) and (4.10) we have $U(m_k, v) > U(\emptyset, v)$ iff $F(\omega_v)(\tau - \zeta)(2p - 1) > 0$, which always holds since $F(\omega_v) > 0$, $\tau > \zeta$ and $p > 1/2$. This proves the first case of part (b.ii) the proposition.

Suppose $p < 1 - F(\omega_v)$, and $p > \frac{1}{\sqrt{2}}$, then from Lemma 5 part (b.ii) it follows that under media the welfare of the DM is

$$\begin{aligned} U(m_k, v) &= \left(\frac{F(\omega_v)}{1-p}\right)(p\tau + (1-p)\zeta) + \left(1 - \frac{F(\omega_v)}{1-p}\right)\tau \\ &= F(\omega_v)\zeta + (1 - F(\omega_v))\tau \end{aligned}$$

By comparing above expression with (4.10) we find that $U(\emptyset, v) = U(m_k, v)$, and hence this proves the second case of part (b.ii) of the proposition, thereby completing the proof.

Proof of Lemma 6 :

Consider the case where a separating voting strategy is followed by all $j \in I, j \neq i$. Let $E(n-1, k)$ be the event that out of $n-1$ private signals, exactly k equal X, $k = 0, \cdots, n-1$. Voter i is pivotal if and only if $k = \frac{n-1}{2}$. We shall use the shorthand $Piv_i = E\left(n-1, \frac{n-1}{2}\right)$. Let

$$\tilde{\gamma}_{s_i} = \mathbf{P}[\omega \leq \omega_v | Piv_i, s_i] = \frac{A}{B}$$

where

$$\begin{aligned} A &= \mathbf{P}[Piv_i, s_i | \omega \leq \omega_v]\mathbf{P}[\omega \leq \omega_v] \\ &= \mathbf{P}[Piv_i | \omega \leq \omega_v]\mathbf{P}[s_i | \omega \leq \omega_v]\mathbf{P}[\omega \leq \omega_v] \end{aligned}$$

and

$$B = \mathbf{P}[Piv_i, s_i | \omega \leq \omega_v]\mathbf{P}[\omega \leq \omega_v] + \mathbf{P}[Piv_i, s_i | \omega_v < \omega]\mathbf{P}[\omega_v < \omega]$$

$$= \mathbf{P}[Piv_i | \omega \leq \omega_v]\mathbf{P}[s_i | \omega \leq \omega_v]\mathbf{P}[\omega \leq \omega_v] + \mathbf{P}[Piv_i | \omega_v < \omega]\mathbf{P}[s_i | \omega_v < \omega]\mathbf{P}[\omega_v < \omega]$$

Note that

$$\mathbf{P}[Piv_i | \omega \leq \omega_v] = \mathbf{P}[Piv_i | \omega > \omega_v] = \binom{n-1}{\frac{n-1}{2}} p^{\frac{n-1}{2}} (1-p)^{\frac{n-1}{2}}$$

Given the prior density $f(\omega)$ with the associated distribution $F(\omega)$,

$$\tilde{\gamma}_X = \frac{pF(\omega_v)}{pF(\omega_v) + (1-p)(1-F(\omega_v))}$$

and

$$\tilde{\gamma}_Y = \frac{(1-p)F(\omega_v)}{(1-p)F(\omega_v) + p(1-F(\omega_v))}.$$

Note that under the simple majoritarian aggregation rule, $\tilde{\gamma}_{s_i} = \gamma_{s_i}$, where $\gamma_{s_i} = \mathbf{P}[\omega \leq \omega_v|s_i]$ is defined in the proof of Lemma 3. Fix any symmetric voting strategy profile v_{-i}. Define

$$U_X(\emptyset, v_{-i}, s_i) = \sum_{k=0}^{n-1} \left[\mathbf{P}[E(n-1,k)|s_i] \left(\int_{\omega \in \Omega} u(\delta(v_{-i}, v_i = X), w) f(\omega|s) d\omega \right) \right],$$

and

$$U_Y(\emptyset, v_{-i}, s_i) = \sum_{k=0}^{n-1} \left[\mathbf{P}[E(n-1,k)|s_i] \left(\int_{\omega \in \Omega} u(\delta(v_{-i}, v_i = Y), w) f(\omega|s) d\omega \right) \right].$$

At this voting strategy profile v_{-i}, voter i votes for X if and only if $U_X(\emptyset, v_{-i}, s_i) > U_Y(\emptyset, v_{-i}, s_i)$. This reduces to

$$(2\tilde{\gamma}_{s_i} - 1)\tau > (2\tilde{\gamma}_{s_i} - 1)\zeta.$$

Since $\tau > \zeta$, the above inequality holds if and only if $(2\tilde{\gamma}_{s_i} - 1) > 0$, which implies $\tilde{\gamma}_{s_i} > 1/2$.

Hence for a separating strategy profile v where $v_i(\emptyset, X) = X$ and $v_i(\emptyset, Y) = Y$ for any $i \in I$ to hold in equilibrium, both the conditions $\tilde{\gamma}_X > 1/2$ and $\tilde{\gamma}_Y < 1/2$ need to be satisfied.

Now consider the scenario where either of the condition $\tilde{\gamma}_X > 1/2$ and $\tilde{\gamma}_Y < 1/2$ is violated, in which case it follows that a separating voting strategy cannot be sustained in a symmetric equilibrium. In this case we consider other possible symmetric equilibria which are (i) $v_i = X$ for each $s_i \in S$ for all $i \in I$ or (ii) $v_i = Y$ for each $s_i \in S$ for all $i \in I$. Note that if for all $j \in I, j \neq i$, the voting strategy $v_j = X$ for each $s_j \in S$ is followed, then voter i is never pivotal. Furthermore, for this case $\mathbf{Pr}(w < w_v | v_{-i}, s_i) = \mathbf{Pr}(w < w_v | s_i)$. In an informative equilibrium, since the preference of the voter is $X \succ Y$ if $\omega \leq \omega_v$ and $Y \succ X$ if $\omega > \omega_v$, upon receiving a private signal $s_i = X$ the voter i votes $v_i = X$ if $\gamma_X > 1/2$ and $v_i = Y$ if $\gamma_X < 1/2$. Similarly, upon receiving a private signal $s_i = Y$ the voter i votes $v_i = X$ if $\gamma_Y > 1/2$ and $v_i = Y$ if $\gamma_Y < 1/2$. These two observations along with the fact that $\tilde{\gamma}_{s_i} = \gamma_{s_i}$ completes the proof.

We now state and prove the following Claim:

Claim 3. *Let* $J(n,p) = \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (p)^j (1-p)^{n-j}$. *Then* $J(n,p)$ *is increasing in* n.

Proof of Claim 3 :

Following Proposition 1 in Karotkin and Paroush (2003), we may express

$$\begin{aligned} J(n+2,p) - J(n,p) &= \binom{n}{\frac{n-1}{2}} p^{\frac{n-1}{2}} (1-p)^{n-\frac{n-1}{2}} p^2 \left(\frac{p}{1-p}\right) \left(\frac{1-p}{p} - \left(\frac{1-p}{p}\right)^2\right) \\ &= \binom{n}{\frac{n-1}{2}} p^{\frac{n+5}{2}} (1-p)^{\frac{n-1}{2}} \left(\frac{1-p}{p} - \left(\frac{1-p}{p}\right)^2\right) \end{aligned}$$

Hence the sufficient condition for $J(n+2,p) - J(n,p) > 0$ is $\frac{1-p}{p} - (\frac{1-p}{p})^2 > 0$, which holds in our model since $p \in (1/2, 1)$. This proves the claim.

Proof of Lemma 7 :

Consider $1/2 < p < F(\omega_v)$. The result follows directly from Lemma 3 case (a.ii) and Lemma 6.

Let $1/2 < F(\omega_v) < p$. Note that $\mathbf{P}[\omega < \omega_v | s_i, m_k, Piv_i] = \mathbf{P}[\omega < \omega_v | s_i, m_k]$ for all k.

Consider the Class 1 and Class 2 message strategies defined in the proof of Lemma 4. It follows from the proof of Lemma 4 that the optimum value of ex-ante payoff of the media under Class 1 message strategies is given by (4.1). The ex-ante payoff of the media under equilibria in Class 2 is given by

$$\mathbf{E}[u_m]_2 = \int_0^{\alpha} \tau_m f(\omega) d\omega + \int_{\alpha}^{\omega_v} (J(n,p)\tau_m + (1 - J(n,p))\zeta_m) f(\omega) d\omega + \int_{\omega_v}^{\beta} ((1 - J(n,p))\tau_m + J(n,p)\zeta_m) f(\omega) d\omega + \int_{\beta}^{1} \zeta_m f(\omega) d\omega$$

where $J(n,p) = \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (p)^j (1-p)^{n-j}$, which is simplified as

$$\mathbf{E}[u_m]_2 = (F(\alpha)+F(\beta))(1-J(n,p))(\tau_m-\zeta_m)+F(\omega_v)(1-2J(n,p))(\zeta_m-\tau_m)+\zeta_m \quad (4.11)$$

Since $\tau_m > \zeta_m$ and $0 < J(n,p) < 1$, this implies that in order to maximize the ex-ante payoff of the media $(F(\alpha) + F(\beta))$ needs to be maximized subject to: (i) $\frac{p}{1-p}(F(\omega_v) - F(\alpha)) + F(\omega_v) > F(\beta)$, (ii) $\frac{1-p}{p}(F(\omega_v) - F(\alpha)) + F(\omega_v) < F(\beta)$, (iii) $0 \leq F(\alpha) < F(\omega_v)$, and (iv) $F(\omega_v) < F(\beta) \leq 1$. We denote this optimization problem as $(**)$. Note that the optimization problems $(**)$ and $(*)$, the latter defined in the proof of Lemma 4 are identical. Hence analogous to the proof of Lemma 4 it follows that the optimum value of β is given by the relation $F(\beta^{**}) = 1$, which implies $\beta^{**} = 1$, and the optimal α^{**} must satisfy the condition $F(\alpha^{**}) = \frac{F(\omega_v)}{p} - \frac{1-p}{p}$. Replacing the optimum values of α^{**} and β^{**} in (4.11), we have the maximum ex-ante payoff of the media under equilibria belonging to Class 2 to be

$$\mathbf{E}[u_m]_2^{**} = \left(\frac{F(\omega_v)}{p} - \frac{1-p}{p} + 1 \right) (1-J(n,p))(\tau_m-\zeta_m)+F(\omega_v)(1-2J(n,p))(\zeta_m-\tau_m)+\zeta_m \quad (4.12)$$

After having described the equilibria which corresponds to the highest ex-ante payoff of the media in Class 1 and Class 2, we compare the ex-ante payoff of the media between these two equilibria. From (4.1) and (4.12) it follows that

$$\mathbf{E}[u_m]_2^{**} - \mathbf{E}[u_m]_1^{**} = \frac{V}{p} \tag{4.13}$$

where $V = (\tau_m - \zeta_m)(J(n,p)(F(\omega_v) - 1)(2p-1) + p(2 - F(\omega_v)) - 1)$.

We now show that $\mathbf{E}[u_m]_2^{**} - \mathbf{E}[u_m]_1^{**} < 0$ holds for all $n \geq 3$, which is proved if the following (4.14) can be shown to hold for all $n \geq 3$

$$J(n,p)(F(\omega_v) - 1)(2p-1) + p(2 - F(\omega_v)) - 1 < 0 \tag{4.14}$$

Let $K(n, p, F(\omega_v)) = J(n,p)(F(\omega_v) - 1)(2p-1) + p(2 - F(\omega_v)) - 1$. Note that since $F(\omega_v) < 1$ and $p > 1/2$, we have $\frac{\partial K(n,p,F(\omega_v))}{\partial J(n,p)} < 0$. From Claim 3 it follows that if (4.14) can be shown to hold for $n = 3$, it will hold for $n > 3$. Note that when $n = 3$, we have $J(3,p) = 3p^2(1-p) + p^3$. Hence we have

$$K(3, p, F(\omega_v)) = 4p^4(1 - F(w_p)) + 8p^3(F(\omega_v) - 1) + 3p^2(1 - F(w_p)) + p(2 - F(\omega_v)) - 1$$

Note that $\frac{\partial K(3,p,F(\omega_v))}{\partial F(\omega_v)} = -p(4p^3 - 8p^2 + 3p + 1)$. Also note that $\frac{\partial K(3,p,F(\omega_v))}{\partial F(\omega_v)}|_{p=1/2} = -1/2$, $\frac{\partial K(3,p,F(\omega_v))}{\partial F(\omega_v)}|_{p=1} = 0$, and $\frac{\partial^2 K(3,p,F(\omega_v))}{\partial p^2} = 0$ has no solution in $p \in (1/2, 1)$. Hence $\frac{\partial K(3,p,F(\omega_v))}{\partial F(\omega_v)} < 0$ for all $p \in (1/2, 1)$. Therefore the maximum value of $K(3, p, F(\omega_v))$ is attained at $K(3, p, 1/2) = 2p^4 - 4p^3 + \frac{3p^2}{2} + \frac{3p}{2} - 1$. Now $K(3, p, 1/2)|_{p=1/2} = -\frac{1}{4}$, $K(3, p, 1/2)|_{p=1} = 0$, and $\frac{\partial K(3,p,1/2)}{\partial p} = 0$ has no solution in $p \in (1/2, 1)$. Hence $K(3, p, F(\omega_v)) < 0$ for all $p \in (1/2, 1)$, $F(\omega_v) \in (1/2, 1)$.

We now argue that the optimum equilibrium obtained under Class 1 corresponds to the maximum ex-ante payoff of the media among all possible equilibria. Note that under Class 1 equilibria, $\mathbf{E}[u_m]$ is increasing in $\hat{w}$, and the maximum value of $\hat{w}$ under Class 1 is when the condition $F(\hat{w}) = \frac{F(\omega_v)}{p}$ is satisfied. When $F(\hat{w}) > \frac{F(\omega_v)}{p}$ then $\hat{\gamma_Y} < 1/2$ and we revert to equilibria under Class 2 with $\alpha = 0$, $\beta = \hat{w}$ which has been proved to have a lower expected payoff for the media than the optimum Class 1 equilibrium. This concludes the proof.

Proof of Lemma 8 : Since $\mathbf{P}[\omega < \omega_v | s_i, m_k, Piv_i] = \mathbf{P}[\omega < \omega_v | s_i, m_k]$ for all k, it follows from the proof of Lemma 4 that the optimum value of ex-ante payoff of the media, denoted by $\mathbf{E}[u_m]_1^{**}$ under Class 1 message strategies (as defined in the proof of Lemma 4) is given by (4.1). Consider Class 2 message strategies as defined in the proof of Lemma 4. From the proof of Lemma 7 it follows that the message strategy which maximizes the ex-ante payoff of the speaker is obtained by solving the optimization problem $(**)$.

Now consider $F(\omega_v) < 1/2$, and $p > 1 - F(\omega_v)$, which implies $1 < \frac{F(\omega_v)}{1-p}$. In this case the solution of $(**)$ is given by $(\alpha^{**}, \beta^{**})$ such that $F(\beta^{**}) = 1$ and $F(\alpha^{**}) = \frac{F(\omega_v)}{p} - \frac{1-p}{p}$. Replacing the optimum values of α^{**} and β^{**} in (4.11), we have the maximum ex-ante payoff of the media under Class 2 message strategies to be given by (4.12). Parts (a.i) and (a.ii) of this lemma therefore follows from (4.14).

Now consider $F(\omega_v) < 1/2$, and $p < 1 - F(\omega_v)$, which implies $\frac{F(\omega_v)}{1-p} < 1$. In this case the solution of $(**)$ is given by (α^{**},β^{**}) such that $F(\alpha^{**}) = 0$, and $F(\beta^{**}) = \frac{F(\omega_v)}{1-p}$. Replacing the optimum values of α^{**} and β^{**} in (4.11) , we have the maximum ex-ante payoff of the media under equilibria belonging to Class 2 to be

$$\mathbf{E}[u_m]_2^{**} = (\frac{F(\omega_v)}{1-p})(1 - J(n,p))(\tau_m - \zeta_m) + F(\omega_v)(1 - 2J(n,p))(\zeta_m - \tau_m) + \zeta_m \quad (4.15)$$

From (4.1) and (4.15) it follows that

$$\mathbf{E}[u_m]_1^{**} - \mathbf{E}[u_m]_2^{**} = \frac{D}{p(1-p)}$$

where $D(\omega_v, n, p) = F(\omega_v)(\tau_m - \zeta_m)(J(n,p)p(2p-1) - p^2 - p + 1)$.

Let $\eta(n,p) = J(n,p)p(2p-1) - p^2 - p + 1$. Since $p > 1/2$, therefore $\eta(n,p)$ is increasing in $J(n,p)$, which by Claim 3 is increasing in n. Note that $\eta(5,1/2) = 1/4$, $\eta(5,1) = 0$, and $\eta(5,p) = 0$ does not have a solution in $p \in (1/2,1)$. Hence $\eta(5,p) > 0$ for all $p \in (1/2,1)$, which implies $D(\omega_v,5,p) > 0$ for all $p \in (1/2,1)$. Since $D(\omega_v,5,p)$ is increasing in n, this proves part (b.i) of the lemma.

To prove part (b.ii), consider $n = 3$. Note that $\eta(3,1/2) = 1/4$, $\eta(3,1) = 0$, and $\eta(3,p) = 0$ has a unique solution in $p \in (1/2,1)$ given by $p' = \frac{(27-3\sqrt{78})^{\frac{1}{3}}}{6} + \frac{(3\sqrt{78}+27)^{\frac{1}{3}}}{6} \approx .76$. This shows that for all $p \in (1/2,p')$, we have $D(\omega_v,3,p) > 0$ while for all $p \in (p',1)$, we have $D(\omega_v,3,p) < 0$. This proves part (b.ii) of the lemma and completes the proof.

Proof of Proposition 4 :

Consider $1/2 < p < F(\omega_v)$. It follows from Lemma 3 part (a.ii), Lemma 6 and Lemma 7 that in equilibrium, for both the cases when the media is absent or present, the voter welfare is given by

$$U(\emptyset,v) = U(\Omega,v) = \int_0^{\omega_v} \tau f(\omega)d\omega + \int_{\omega_v}^1 \zeta f(\omega)d\omega = F(\omega_v)\tau + (1-F(\omega_v))\zeta$$

This proves part (a) of the proposition.

Consider $1/2 < F(\omega_v) < p$. From Lemma 3 part (a.i) and Lemma 6 it follows that in the absence of a media the ex-ante voter welfare is given by

$$U(\emptyset,v) = J(n,p)\tau + (1-J(n,p))\zeta,$$

where

$$J(n,p) = \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} p^j (1-p)^{n-j}.$$

From Lemma 7 it follows that in the presence of a media, the most influential equilibrium (m_k,v) results in the ex-ante voter welfare given by

$$U(m_k, v) = \tau F(\omega_v) + \zeta(\frac{F(\omega_v)}{p} - F(\omega_v)) + \tau(1 - \frac{F(\omega_v)}{p}).$$

Hence $U(\emptyset, v) > U(m_k, v)$ if

$$\frac{(\tau - \zeta)(J(n,p)p - p(F(\omega_v) + 1) + F(\omega_v))}{p} > 0,$$

which holds if the following condition (4.16) is satisfied.

$$F(\omega_v) > \frac{p}{1-p}(1 - J(n,p)) = G(n,p). \tag{4.16}$$

We now state and prove two additional claims:

Claim 4. *For all p below $(1/2)(1 + \frac{2}{n+1})$, any critical point of $G(n,p)$ is a strict local maximum and any critical point above is a strict local minimum.*

Proof of Claim 4 : Let $L_{n,j}(p) \equiv \binom{n}{j} p^j (1-p)^{n-j}$. Also let

$$F_{n,r}(p) \equiv \sum_{j=0}^{r} \binom{n}{j} p^j (1-p)^{n-j} = \sum_{j=0}^{r} L_{n,j}(p).$$

Since n is an odd integer, and let m be an even integer given by $m = \frac{n+1}{2}$. We may express

$$G(n,p) \equiv \frac{p}{(1-p)} F_{n,m-1}(p)$$

At $p = 0$ we replace this definition by its limiting value $G(n,0) = 0$. We also have $G(n,1) = 0$. Note that

$$\frac{d}{dp} L_{n,j}(p) = n\left(L_{n-1,j-1} - L_{n-1,j}\right) \tag{4.17}$$

So

$$\frac{d}{dp} F_{n,m-1}(p) = \sum_{j=0}^{m-1} n\left(L_{n-1,j-1} - L_{n-1,j}\right) = -nL_{n-1,m-1}.$$

Hence we have

$$\frac{d}{dp}G\left(n,p\right)=\frac{1}{(1-p)^{2}}F_{n,m-1}\left(p\right)-\frac{np}{(1-p)}L_{n-1,m-1} \tag{4.18}$$

Differentiating both sides of (4.18) again with respect to p we have

$$\frac{d^{2}}{dp^{2}}G\left(n,p\right)=\frac{2}{(1-p)^{3}}F_{n,m-1}\left(p\right)-\frac{2n}{(1-p)^{2}}L_{n-1,m-1}-n\left(\frac{1}{(1-p)}-1\right)L'_{n-1,m-1}$$

From (4.17) we have

$$L'_{n-1,m-1}=\left(n-1\right)\left(L_{n-2,m-2}-L_{n-2,m-1}\right),$$

and hence

$$\frac{d^{2}}{dp^{2}}G(n,p)=\frac{2}{(1-p)^{3}}F_{n,m-1}\left(p\right)-\frac{2n}{(1-p)^{2}}L_{n-1,m-1}-n\left(n-1\right)\frac{p}{(1-p)}\left(L_{n-2,m-2}-L_{n-2,m-1}\right) \tag{4.19}$$

By the Weierstrass theorem, $G(n,p)$ has at least one global maximum over $[0,1]$.

We now require $G'\left(n,p^{*}\right)=0$, so from (4.18) we have

$$\frac{1}{(1-p^{*})^{2}}F^{*}_{n,m-1}-\frac{np^{*}}{(1-p^{*})}L^{*}_{n-1,m-1}=0$$

where $F^{*}_{n,m-1}\equiv F_{n,m-1}\left(p^{*}\right)$ etc.

For maximization we require $G''\left(n,p^{*}\right)\leq 0$, so from (4.19) we have

$$\frac{2}{(1-p^{*})^{3}}F^{*}_{n,m-1}-\frac{2n}{(1-p^{*})^{2}}L^{*}_{n-1,m-1}-n\left(n-1\right)\frac{p^{*}}{(1-p^{*})}\left(L^{*}_{n-2,m-2}-L^{*}_{n-2,m-1}\right)\leq 0$$

Using the first-order condition, the second order condition is equivalent to

$$-2n(1-p^{*})L^{*}_{n-1,m-1}-n\left(n-1\right)p^{*}(1-p^{*})\left(L^{*}_{n-2,m-2}-L^{*}_{n-2,m-1}\right)\leq 0,$$

which is further simplified as,

$$2+\left(n-1\right)p^{*}\left(\frac{m-1}{n-1}\frac{1}{p^{*}}-\frac{n-m}{n-1}\frac{1}{(1-p^{*})}\right)\geq 0$$

$$\Leftrightarrow m+1 \geq (n+1)\, p^{*}.$$

Using $n = 2m-1$ we can write the above inequality as $p^{*} \leq \frac{m+1}{2m}$, which implies that

$$p^{*} \leq (1/2)\left(1+\frac{1}{m}\right). \tag{4.20}$$

Thus it follows from (4.20) that any critical point below $(1/2)\left(1+\frac{1}{m}\right)$ is a strict local maximum and any critical point above is a strict local minimum. Putting $m = \frac{n+1}{2}$ proves the claim.

Claim 5. $\frac{dG(n,p)}{dp}|_{p=1/2} < 0$ *for all* $n \geq 7$.

Proof of Claim 5 : Note that

$$\frac{\mathbf{d}G(n,p)}{\mathbf{d}p} = \frac{1}{(1-p)^2} - \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} (p)^j (1-p)^{n-j} \left[\frac{j+1}{1-p} - \left(\frac{p}{(1-p)^2}\right)(n-j-1)\right]$$

Hence

$$\frac{\mathbf{d}G(n,p)}{\mathbf{d}p}|_{p=1/2} = 4\left[1 - \left(\frac{1}{2}\right)^{n+1} \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j}(2j+2-n)\right]$$

We want to establish that for $n \geq 7$, $\frac{\partial G(n,p)}{\partial p}|_{p=1/2} < 0$ which implies

$$2^{n+1} < \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j}(2j+2-n) \tag{4.21}$$

Note that $\sum_{j=0}^{n} \binom{n}{j} = 2^n$, and since n is odd, we also have

$$\sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j} = (1/2)\sum_{j=0}^{n} \binom{n}{j}.$$

Using these, we may express (4.21) as

$$2^{n} < \sum_{j=\frac{n+1}{2}}^{n} \binom{n}{j}(2j-n) \tag{4.22}$$

Let $k = \frac{n-1}{2}$. We may express (4.22) as

$$2\left[\binom{2k+1}{k+1} + \binom{2k+1}{k+2} + .. + 1\right] < \binom{2k+1}{k+1} + 3\binom{2k+1}{k+2} + 5\binom{2k+1}{k+3} + .. + (2k+1)$$

which holds if

$$2\left[\binom{2k+1}{k+1}+\binom{2k+1}{k+2}+\binom{2k+1}{k+3}\right] < \binom{2k+1}{k+1}+3\binom{2k+1}{k+2}+5\binom{2k+1}{k+3}$$

Using the relation

$$\binom{n}{j+1} = \binom{n}{j}\frac{n-j}{j+1},$$

the above inequality reduces to

$$\frac{k}{k+2}+\frac{3k(k-1)}{(k+2)(k+3)} > 1$$

Consider

$$g(k) = \frac{k}{k+2}+\frac{3k(k-1)}{(k+2)(k+3)} - 1.$$

Note that for $k > 0$, the equation $g(k) = 0$ has a unique solution at $k = \frac{\sqrt{97}}{6} + \frac{5}{6} < 3$, and $\frac{\mathbf{d}g(k)}{\mathbf{d}k}|_{k=\frac{\sqrt{97}}{6}+\frac{5}{6}} > 0$. Hence $g(k) > 0$ for all $k \geq 3$, which implies (4.22) is satisfied for all $n \geq 7$. This proves Claim 5.

Now, note that when $p = 1/2$, then $J(n, 1/2) = 1/2$ for all n and hence $G(n, 1/2) = 1/2$. From Claim 4 we know that for the function $G(n,p)$ any critical point when p is below $(1/2)(1+\frac{2}{n+1})$ must correspond to a *strict* local maximum and therefore cannot be a local minimum. But from Claim 5 we know that when $n \geq 7$, then $\frac{\mathbf{d}G(n,p)}{\mathbf{d}p}|_{p=1/2} < 0$, and hence from Claim 4 it follows that there does not exist any $p \in (1/2, (1/2)(1+\frac{2}{n+1}))$ such that $G(n,p) \geq 1/2$. From Claim 4 it follows that when $n \geq 7$, any critical value of $G(n,p)$ for p above $(1/2)(1+\frac{2}{n+1})$ must correspond to a strict local minimum. Since $G(n,1) = 0$, it must therefore be that $G(n,p) < 1/2$ when $p \in [(1/2)(1+\frac{2}{n+1}), 1)$. Therefore we have shown that when $n \geq 7$, $G(n,p) < 1/2$ for all $p \in (1/2, 1)$.

Since $F(\omega_v) \in (1/2, 1)$, it follows that when $n \geq 7$, the condition $F(\omega_v) > G(n,p)$ holds for all $p \in (1/2, 1)$ and therefore from inequality (4.16) we have $U(\emptyset, v) > U(m_k, v)$. This proves part (b.i) of the proposition.

To prove part (b.ii), consider the case when $n \in \{3, 5\}$.

Let $n = 3$. Note that $G(3, 1/2) = 1/2$, $\frac{\mathbf{d}G(3,p)}{\mathbf{d}p}|_{p=1/2} = 1/2 > 0$, and that in the range $p \in (1/2, 1)$, the equation $\frac{\mathbf{d}G(3,p)}{\mathbf{d}p} = -6p^2 + 2p + 1 = 0$ yields a unique solution given by $p_3^* = \frac{\sqrt{7}}{6} + \frac{1}{6} > 1/2$. Also note that $\frac{\mathbf{d}^2G(3,p)}{\mathbf{d}p^2} = -12p + 2 < 0$ for all $p \in (1/2, 1)$. Hence the maximum value of $G(3, p)$ is $G(3, p_3^*) = \frac{7\sqrt{7}}{54} + \frac{5}{27} = k^*(3)$ which is greater than 1/2 and less than 1. Therefore it follows from (4.16) that when $F(\omega_v) > k^*(3)$, then ex-ante voter welfare is always higher in the absence of a media. This proves part (b.ii.1) of the proposition for $n = 3$.

Suppose $1/2 < F(\omega_v) < k^*(3)$. Since $\frac{\mathbf{d}^2G(3,p)}{\mathbf{d}p^2} < 0$ for all $p \in [1/2, 1]$, it follows that there exists $F(\omega_v) < \hat{p}(3) < p_3^*$ such that for all $p \in (F(\omega_v), \hat{p}(3))$, the inequality $G(3, p) < F(\omega_v)$ holds while for all $p \in (\hat{p}(3), p_3^*)$, the inequality $G(3, p) > F(\omega_v)$ holds. Since $G(3, p_3^*) > 1/2$ and $G(3, 1) = 0$ it follows that there exists $p_3^* < \tilde{p}(3)$ such that for all $p \in [p_3^*, \tilde{p}(3))$, the inequality $G(3, p) > F(\omega_v)$ holds while for all $p \in (\tilde{p}(3), 1)$, the inequality $G(3, p) < F(\omega_v)$ holds. This proves part (b.ii.2) of the proposition for $n = 3$.

Now consider $n = 5$. Note that $G(5, 1/2) = 1/2$, $\frac{\mathbf{d}G(5,p)}{\mathbf{d}p}|_{p=1/2} = \frac{1}{8} > 0$, and that in the range $p \in (1/2, 1)$, the equation $\frac{\mathbf{d}G(5,p)}{\mathbf{d}p} = 30p^4 - 36p^3 + 3p^2 + 2p + 1 = 0$ yields a unique solution given by $p_5^* = \frac{(548-30\sqrt{290})^{\frac{1}{3}}}{30} + \frac{(30\sqrt{290}+548)^{\frac{1}{3}}}{30} + \frac{1}{15}$. Note that $1/2 < p_5^* < p_3^*$ and $1/2 < G(5, p_5^*) < G(3, p_3^*) < 1$. Let $G(5, p_5^*) = k^*(5)$. When $F(\omega_v) > k^*(5)$, it follows from inequality (4.16) that ex-ante voter welfare is higher in the absence of a media. This proves part (b.ii.1) of the proposition for $n = 5$. Suppose $1/2 < F(\omega_v) < k^*(5)$. Since $\frac{\mathbf{d}^2G(5,p)}{\mathbf{d}p^2}|_{p=1/2} < 0$, $\frac{\mathbf{d}^2G(5,p)}{\mathbf{d}p^2}|_{p=p_5^*} < 0$, and the equation $\frac{\mathbf{d}^2G(5,p)}{\mathbf{d}p^2} = 0$ is not solved for $p \in [1/2, p_5^*]$, it follows that $\frac{\mathbf{d}^2G(5,p)}{\mathbf{d}p^2} < 0$ for all $p \in [1/2, p_5^*]$. This proves the existence of $\hat{p}(5)$. Since $G(5, p_5^*) > 1/2$ and $G(5, 1) = 0$, the existence of $\tilde{p}(5)$ is proved. This proves part (b.ii.2) of the proposition for $n = 5$. This concludes the proof.

Proof of Proposition 5 :

Let $1 - p < F(\omega_v)$. From Lemma 3 part (b.i) and Lemma 6 it follows that in this case the ex-ante welfare of the voter in the absence of the media is given by

$$U(\emptyset, v) = J(n,p)\tau + (1 - J(n,p))\zeta \tag{4.23}$$

Now consider the case where the media is present. Suppose $(*)$ holds. From Lemma 8 part (a.i), the ex-ante welfare of the voter in this case is given by

$$U(m_k, v) = \tau F(\omega_v) + \zeta(\frac{F(\omega_v)}{p} - F(\omega_v)) + \tau(1 - \frac{F(\omega_v)}{p}) \tag{4.24}$$

It follows that in this case $U(\emptyset, v) > U(m_k, v)$ if (4.16) holds.

Suppose $(*)$ is always violated, in which case by Lemma 8 part (a.ii) it follows that the ex-ante welfare of the voter is given by

$$U(m_k, v) \quad = \quad \tau(\frac{F(\omega_v)}{p} - \frac{1-p}{p}) + (1 - (\frac{F(\omega_v)}{p} - \frac{1-p}{p}))(J(n,p)\tau + (1 - J(n,p))\zeta) \ .$$

Since $p > 1 - F(\omega_v)$, it follows that $0 < \frac{F(\omega_v)}{p} - \frac{1-p}{p} < 1$ and since $\tau > \zeta$, $0 < J(n,p) < 1$ it follows that for this case $U(m_k, v) > U(\emptyset, v)$. This proves Part (a) of the proposition.

Now consider $F(\omega_v) < 1 - p$. It follows from Lemma 3 part (b.ii) and Lemma 6 that in this case the ex-ante welfare of the voter in the absence of a speaker is given by

$$U(\emptyset, v) = \int_0^{\omega_v} \zeta f(\omega) d\omega + \int_{\omega_v}^1 \tau f(\omega) d\omega = F(\omega_v)\zeta + (1 - F(\omega_v))\tau$$

From Lemma 8 part (b.i) it follows that in the presence of the media, when $n \geq 5$, the ex-ante welfare of the voter is given by (4.24). Hence it follows that $U(m_k, v) > U(\emptyset, v)$ if

$$(\tau - \zeta)(2F(\omega_v) - \frac{F(\omega_v)}{p})) > 0 \tag{4.25}$$

which always holds for all $1/2 < p < 1$. Hence in this case the presence of the media leads to higher voter welfare. When $n = 3$, and $p \in (1/2, p')$ where p' is defined in Lemma 8 part (b.ii), it is analogously shown that (4.25) holds and presence of the media leads to higher voter welfare. When $n = 3$, and $p \in (p', 1)$, from Lemma 8 part (b.ii) it follows that under media presence, the ex-ante voter welfare is given by

$$U(m_k, v) = \left(\frac{F(\omega_v)}{1-p}\right)(J(n,p)\tau + (1 - J(n,p))\zeta) + \left(1 - \frac{F(\omega_v)}{1-p}\right)\tau.$$

Hence it follows that $U(m_k, v) > U(\emptyset, v)$ if

$$\frac{F(\omega_v)(\tau - \zeta)(J(n,p) - p)}{1-p} > 0$$

which always holds since $F(\omega_v) > 0$, $\tau > \zeta$ and $1/2 < p < J(n,p)$. Hence in this case the presence of media leads to higher ex-ante voter welfare. This proves part (b) of the proposition and concludes the proof.

Chapter 5

Conclusion

In the model described in Chapter 3, we show that to obtain informative voting as an equilibrium outcome, it is necessary and sufficient to have a unanimous committee with random transparency when the common prior is not too biased towards a particular alternative. This shows that the simple majority rule can never elicit informative voting from professional experts. We then show that even if there exist unanimous committees with intermediate probabilities of transparency that achieve informative voting, such committees are never welfare maximising, that is, informative voting and welfare maximisation are two mutually exclusive properties of professional committees. In particular it turns out that for committees following the unanimity voting rule there exists a critical value of the common prior such that if the prior falls below that level, full transparency is best for the society, while full secrecy is optimal for priors above that level. We then show that if the common prior is not too biased, a transparent committee using the majority rule is socially better than any committee using the unanimity rule.

These results bring out an interesting conclusion that while only randomness in transparency can achieve truthful voting, such committees are not socially optimal. These findings have interesting implications regarding the recent debate on the effect that independent whistle-blowing agencies (like the Wikileaks) may have on professional expert committees. It suggests that without such exogenous, but moderate, leakage threats we cannot expect professional experts to advise informatively; however, since these experts are possibly heterogeneous in their talent levels, such leakage which elicits perfect informativeness from all the experts may not be welfare enhancing.

In the model described in Chapter 4, we study information transmission where an informed media outlet, whose interests are partially in conflict with a finite group of rational voters, transmits news items in an attempt to manipulate democratic decisions. In a common interest two-alternative voting model, where due to reputation concerns the media can credibly commit to send any news reliably, it is shown that even when voters welcome the news when it arrives, the media's presence can hurt their ex-ante welfare in both large and small constituencies. This is because of the following: due to the credibility of the media, the voters excessively rely on the informative content of the transmitted news to the point that their private signals have no bearing on their voting behaviour. Hence in this case the welfare is invariant to the number of voters, since their signals are not reflected in the decision. On the other hand, in the absence of the media outlet, the voters end up voting in accordance to their private signals. In this case the probability that the social decision will be in accordance to the voters' preference rises as the number of voters rise, since the incidences of informative signals that contribute to the correct decision rise. Therefore for a sufficiently large number of voters, the voter welfare in the absence of the media is higher than when credible news is received from it.

Anderson, S. P. and J. McLaren (2010): "Media Mergers and Media Bias with Rational Consumers", *CEPR Discussion Paper No.* DP7768.

Angeletos, G. M. and A. Pavan (2004): "Transparency of Information and Coordination in Economies with Investment Complementarities", *American Economic Review*, Vol. 94, pp. 91 - 98.

Angeletos, G. M. and A. Pavan (2007): "Efficient use of Information and Social Value of Information", *Econometrica*, Vol. 75 (4), pp. 1103 - 1142.

Aumann, R. J. and S. Hart (2003): "Long Cheap Talk", *Econometrica*, Vol. 71, pp. 1619 - 1660.

Austen-Smith, D. (1990): "Information Transmission in Debate", *American Journal of Political Science*, Vol. 34, pp. 124 - 152.

Austen-Smith, D. (1993): "Interested Experts and Policy Advice: Multiple Referrals under Open Rule", *Games and Economic Behavior*, Vol. 5, pp. 3 - 43.

Austen-Smith, D. and A. Banks (1996): "Information Aggregation, Rationality, and the Condorcet Jury Theorem," *The American Political Science Review*, Vol. 90 (1), pp. 34 - 45.

Austen-Smith, D. and T. J. Feddersen (2006): "Deliberation, Preference Uncertainty, and Voting Rules," *The American Political Science Review*, Vol. 100(2), pp. 209 - 217.

Avery, C. N. and J.A. Chevelier (1999): "Herding over the career", *Economics Letters* Vol. 63, pp. 327 333.

Baliga, S. and S. Morris (2002): "Co-ordination, Spillovers and Cheap Talk," *Journal of Economic Theory*, Vol. 105, pp. 450 - 468.

Baliga, S. and T. Sjostrom (2004): "Arms Races and Negotiations," *Review of Economic Studies*, Vol. 71, pp. 351 - 369.

Banks, J. S. and R. L. Calvert (1992): "A Battle-of-the-Sexes Game with Incomplete Information," *Games and Economic Behavior*, Vol. 4, pp. 347 - 372.

Barreda, I. (2010): "Cheap Talk with Two-Sided Private Information", Working Paper.

Battaglini, M. (2002): "Multiple Referrals andMultidimensional Cheap Talk," *Econometrica*, Vol. 70, pp. 1379 - 1401.

Benabou, R. and G. Laroque (1992): "Using Privileged Information to Manipulate Markets Insiders, Gurus, and Credibility," *The Quarterly Journal of Economics*, Vol. 107, pp. 921 - 958.

Besley, T. and A. Prat (2006): "Handcuffs for the Grabbing Hand? Media Capture and Government Accountability", *American Economic Review*, Vol. 96, pp. 72 - 76.

Bikchandani, S., D. Hirshleifer and I. Welch (1992): "A Theory of Fads, Fashion, Custom, and Cultural Change in Informational Cascades", *Journal of Political Economy*, Vol. 100 (5), pp. $992 - 1026$.

Cao, H. and D. Hirshleifer (2000): "Conversation, Observational Learning and Informational Cascades", Working Paper No. 2001-5, Ohio State University.

Condorcet, M. (1785): "Essai sur l'application de l'analyse á la probabilité des decisions rendues a la pluralite dés voix", *Paris: L'imprimerie royale.*

Chakraborty, A. and R. Harbaugh (2003): "Cheap Talk Comparisons in Multi-issue Bargaining", *Economics Letters*, Vol. 78, pp. 357 - 363.

Chakraborty, A., P. Ghosh and J. Roy (2012): "Policy Persuasion and Electoral Competition", Mimeo, University of Birmingham.

Chakraborty, A. and P. Ghosh (2012): "Candidate Endorsements and Electoral Competition", Working Paper, Delhi School of Economics, Delhi.

Chen, Y. (2011): "Perturbed Communication Games with Honest Senders and Naive Receivers", *Journal of Economic Theory*, Vol. 146 (2), pp. 401 - 424.

Crawford, V. and J. Sobel (1982): "Strategic Information Transmission", *Econometrica*, Vol. 50 (6), pp. 1431 - 1451.

Crawford, V. (2003): "Lying for Strategic Advantage: Rational and Boundedly Rational Misrepresentation of Intentions," *American Economic Review*, Vol. 93, pp. 133 - 149.

Dessein, W. (2002): "Authority and Communication in Organizations", *Review of Economic Studies*, Vol. 69 (4), pp. 811 - 838.

Druckman, J. and A. Lupia (2000): "Preference Formation," *Annual Review of Political Science*, Vol. 3, pp. 1 - 24.

Durante, R. and B. Knight (2012): "Partisan Control, Media Bias and Viewer Responses: Evidence from Berlusconi's Italy", *Journal of European Economic Association*, Vol. 10 (3).

Effinger, M. R. and M. K. Polborn (2001): "Herding and anti-herding: A model of reputational differentiation", *European Economic Review*, Vol. 45, pp. 385 403.

Fama, E. (1980): "Agency Problems and the Theory of the Firm", *Journal of Political Economy*, Vol. 88, pp. 288 - 307.

Farrell, J. and R. Gibbons (1989): "Cheap Talk with Two Audiences," *American Economic Review*, Vol. 79, pp. 1214 - 1223.

Farrell, J. and M. Rabin (1996): "Cheap Talk", *Journal of Economic Perspectives*, Vol. 10, pp. 103 - 118.

Feddersen, T. J. and W. Pesendorfer (1996): "The Swing Voter's Curse", *American Economic Review*, Vol. 86 (3), pp. 408 - 424.

Feddersen, T. and W. Pesendorfer (1997): "Voting Behavior and Information Aggregation in Elections with Private Information", *Econometrica*, Vol. 65, pp. 1029 - 1058.

Feddersen, T. J. and W. Pesendorfer (1998): "Convicting the Innocent: The Inferiority of Unanimous Jury Verdicts under Strategic Voting", *American Political Science Review*, Vol. 92 (1), pp. 23 - 35.

Fingleton, J. and M. Raith (2005): "Career Concerns of Bargainers," *Journal of Law, Economics and Organization*, Vol. 21(1), pp. 179 - 204.

Forges, F. and F. Koessler (2005): "Communication Equilibria with Partially Verifiable Types", *Journal of Mathematical Economics*, Vol. 41, pp. 793 - 811.

Ganguly, C. and I. Ray (2010): "Cheap Talk: Basic Models and New Developments." In Dhar, A. (ed.), Some Contemporary Issues on Development and Growth Economics, pp. 383 - 416, Allied Publishers (India).

Gentzkow, M. and J. Shapiro (2006): "Media Bias and Reputation," *Journal of Political Economy*, Vol. 114, pp. 280 - 316.

Gerling, K., Gruner, H. P., Kiel, A. and E. Schulte (2005): "Information acquisition and decision making in committees: A survey," *European Journal of Political Economy*, Vol. 21 (3), pp. 563 - 597.

Gersbach, H. (2000): "Public information and social choice," *Social Choice and Welfare*, Vol. 17, pp. 25 - 31.

Gersbach, H. (1995): "Information Efficiency and Majority Decisions", *Social Choice and Welfare*, Vol. 12, pp. 363 - 370.

Gersbach, H. and V. Hahn (2001): "Should the Individual Voting Records of Central Bankers be Published?", *Deutsche Bundesbank Discussion Paper*, Number 02/01.

Gersbach, H. and V. Hahn (2012): "Information acquisition and transparency in committees", *International Journal of Game Theory*, Vol. 41 (2), pp. 427 - 453.

Gilligan, T. W. and K. Krehbiel (1989): "Asymmetric Information and Legislative Rules with a Heterogeneous Committee", *American Journal of Political Science*, Vol. 33 (2), pp. 459 - 490.

Glazer, J. and A. Rubinstein (2004): "On Optimal Rules of Persuasion", *Econometrica*, Vol. 72 (6), pp. 1715 - 1736.

Grossman, S. J. (1981): "The Informational Role of Warranties and Public Disclosure about Product Quality", *Journal of Law and Economics*, Vol. 24, pp. 461 - 483.

Grossman, G. and E. Helpman (1999): "Competing for Endorsements," *American Economic Review*, Vol. 89, pp. 501 - 524.

Hellwig, C. (2005): "Heterogeneous information and the welfare effects of pubic information disclosures," mimeo, UCLA.

Hirshleifer, J. (1971): "The Private and Social Value of Information and the Reward to Inventive Activity," *American Economic Review*, Vol. 61 (4), pp. 561 - 574.

Holmstrom, B. (1999): "Managerial Incentive Problems: A Dynamic Perspective," *Review of Economic Studies*, Vol. 66, pp. 169 182.

Holmstrom, B. and J. Ricart i Costa (1986): "Managerial Incentives and Capital Management", *Quarterly Journal of Economics*, Vol. 101 (4), pp. 835 860.

Ivanov, M. (2010): "Informational Control and Organizational Design," *Journal of Economic Theory*, Vol. 145, pp. 721 - 751.

Iyenger, S. and D. Kinder (1987): "News that matters: Television and American Opinion", *Chicago University Press*.

Karotkin, D. and J. Paroush (2003): “Optimum Committee Size: Quality-versus-quantity Dilemma”, *Social Choice and Welfare*, Vol. 20 (3), pp. 429 - 441.

Kinder, D. (1998): “Communication and Opinion”, *Annual Review of Political Science*, Vol. 1, pp. 167 - 197.

Koessler, F. (2004): “Strategic knowledge sharing in Bayesian games”, *Games and Economic Behavior*, Vol. 48, pp. 292 - 320.

Kreps, D.M. and R. Wilson (1982). “Reputation and imperfect information”, *Journal of Economic Theory*, Vol. 27(2), pp. 253 279.

Krishna, V. and J. Morgan (2001a): “A Model of Expertise”, *The Quarterly Journal of Economics*, Vol. 116 (2), pp. 747 - 775.

Krishna, V. and J. Morgan (2001b): “Asymmetric Information and Legislative Rules: Some Amendments”, *American Political Science Review*, Vol. 95, pp. 435 - 457.

Krishna, V. and J. Morgan (2004): “The Art of Conversation: Eliciting Information from Experts through Multi-Stage Communication,” *Journal of Economic Theory*, Vol. 117, pp. 147 - 179.

Lai, E. K. (2010): “Expert Advice for Amateurs”, Mimeo.

Levy, G. (2004): “Anti-herding and Strategic Consultation”, *European Economic Review*, Vol. 48 (3), pp. 503-525.

Levy, G. (2007a): “Decision Making in Committees: Transparency, Reputation, and Voting Rules,” *American Economic Review*, Vol. 97(1), pp. 150-168.

Levy, G. (2007b): “Decision Making Procedures for Committees of Careerist Experts,” *American Economic Review, Papers and Proceedings*, Vol. 97 (2), pp. 306 - 310.

Levy, G. and R. Razin (2007): "On The Limits of Communication in Multidimensional Cheap Talk: A comment", *Econometrica*, Vol. 75 (3), pp. 885 - 894.

Lichter, S., Rothman, S., and L. Lichter (1986): "The Media Elite: America's New Power-brokers," Bethesda, MD: Adler and Adler.

Lupia, A. and M. D. McCubbins (1998): "The Democratic Dilemma: Can Citizens Learn What They Need To Know?", *Cambridge University Press.*

Matthews, S. A. and A. Postlewaite (1989): "Pre-Play Communication in Two-Person Sealed-Bid Double Auctions", *Journal of Economic Theory*, Vol. 48, pp. 238 - 263.

Meade, E. E. and D. Stasavage (2008): "Publicity of Debate and the Incentive to Dissent: Evidence from the US Federal Reserve", *The Economic Journal*, Vol. 118, pp. 695 - 717.

Mertens, J. and S. Zamir (1985): "Foundation of Bayesian analysis for games with incomplete information", *International Journal of Game Theory*, Vol. 14, pp. 1 - 29.

Milgrom, P. (1981): "Good News and Bad News: Representation Theorems and Applications", *Bell Journal of Economics*, Vol. 12, pp. 380 391.

Milgrom, P. and J. Roberts (1982): "Predation, reputation and entry deterrence", *Journal of Economic Theory*, Vol. 27 (2), pp. 280 312.

Morgan, J. and P. C. Stocken (2003): "An analysis of stock recommendations", *RAND Journal of Economics*, Vol. 34 (1), pp. 183 - 203.

Morris, S. (2001): "Political Correctness", *Journal of Political Economy*, Vol. 109, pp. 231 - 265.

Morris, S. and H. Shin (2002): "The Social Value of Public Information", *American Economic Review*, Vol. 92, pp. 1521 - 1534.

Mullainathan, S. and A. Shleifer (2005): "The Market for News", *American Economic Review*, Vol. 95, pp. 1031 - 1053.

Mutz, D., Sniderman, P., and R. Brody (1996): "Political Persuasion and Attitude Change,", Discussion Paper, Ann Arbor, University of Michigan.

Okuno-Fujiwara, M., Postlewaite, A., and K. Suzumura (1990): "Strategic Information Revelation," *The Review of Economic Studies*, Vol. 57, pp. 25 - 47.

Ottaviani, M., and P. N. Sorensen (2001): "Information aggregation in debate: who should speak first?", *Journal of Public Economics*, Vol. 81, pp. 393 - 421.

Ottaviani, M., and P. N. Sorensen (2006a): "Professional Advice", *Journal of Economic Theory*, Vol. 126 (1), pp. 120 - 142.

Ottaviani, M., and P. N. Sorensen (2006b): "Reputational Cheap Talk", *RAND Journal of Economics*, Vol. 37 (1), pp. 155 - 175.

Persico, N. (2004): "Committee Design with Endogenous Information", *Review of Economic Studies*, Vol. 71 (1), pp. 165 - 191.

Scharfstein, D. S and J. C. Stein (1990): "Herd behaviour and investment," *American Economic Review*, Vol. 80 (3), pp. 465 479.

Seidmann, D. (1990): "Effective Cheap Talk with Conflicting Interests," *Journal of Economic Theory*, Vol. 50, pp. 445 - 458.

Shin, H.S. (1994): "The burden of proof in a game of persuasion", *Journal of Economic Theory*, Vol. 64, pp. 253 264.

Sobel, J. (1985): "A Theory of Credibility," *The Review of Economic Studies*, Vol. 52, pp. 557 - 573.

Stasavage, D. (2007): "Polarization and Publicity: Rethinking the Benefits of Deliberative Democracy", *Journal of Politics*, Vol. 69 (1), pp. 59 - 72.

Stromberg, D. (2004): "Mass Media Competition, Political Competition and Public Policy", *Review of Economic Studies*, Vol. 71, pp. 265 - 284.

Swank O. H. and B. Visser (2010): "Is transparency to no avail?", *Tinberegen Institute Discussion Paper.*

Visser, B. and O. H. Swank (2007), "On Committees of Experts," *Quarterly Journal of Economics*, Vol. 122 (1), pp. 337 - 372.

Watts, M. D., Domke, D., Shah D. V., and D. P. Fan (1999): "Elite Cues and Media Bias in Presidential Campaigns: Explaining public perceptions of a liberal press", *Comminication Research*, Vol. 26 (2), pp. 144 - 175.

Zaller, J. (1992): "The Nature and Origins of Mass Opinion", *Cambridge University Press.*

Zwiebel, J. (1995): "Corporate Conservatism and Relative Compensation", *Journal of Political Economy*, Vol. 103 (1), pp. 1 25.